
TURN THE
LEAF AND GLEAN
THE FRUIT
ADDISON CAIRNS MIZNER
HIS BOOK
NO
DATE

ENCYCLOPEDIA OF ARCHITECTURE.

A

DICTIONARY

OF THE

SCIENCE AND PRACTICE

OF

Architecture, Building, Carpentry, Etc.,

FROM

THE EARLIEST AGES TO THE PRESENT TIME,

FORMING A COMPREHENSIVE WORK OF REFERENCE FOR THE USE OF ARCHITECTS, BUILDERS, CARPENTERS, MASONS, ENGINEERS, STUDENTS, PROFESSIONAL MEN, AND AMATEURS.

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EDITED BY

EDWARD LOMAX AND THOMAS GUNYON,

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ILLUSTRATED WITH TWO HUNDRED AND THIRTY ENGRAVINGS ON STEEL,

MOSTLY FROM WORKING DRAWINGS IN DETAIL.

IN TWO VOLUMES.

VOL. I.

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PREFACE

It is the design of the present work to give an account, not only of Architecture itself, but also of the various other Arts and Sciences connected with it, and without which a comprehensive and complete knowledge of it cannot be attained.

An alphabetical arrangement was adopted by the author, Mr. P. Nicholson, as considered the best adapted for the use of mechanics, as well as the most expeditious, a knowledge of the meaning of the terms of art, which are very numerous, being more easily acquired by this mode than by any other.

The Rise and Progress of every department are given as far as authentic information could be obtained. The greatest attention has been paid to the Definitions; and it is hoped that they will be found to be far more intelligible than those which have been hitherto given in Dictionaries, and in Treatises on Architecture. Geometry being the key to works of this description, such Geometrical Problems are introduced as will be found useful in delineating the various kinds of objects that may occur.

Orthographical and Perspective Drawing being necessary, not only to the Architect, but also to the Builder and Workman, their principles are laid down, and their application is shown by means of numerous examples.

Carpentry and Joinery, also, are here treated in a manner far superior to that which characterizes any previous work upon those subjects.

In the other branches has been given, *not only what has fallen under the immediate observation of the author*, but also the *valuable information* which has resulted from the diligent inquiries he has made of the most skilful workmen. An account, also, of the Properties of the Materials used in the execution of works, and of the Rules for judging of their quality, is given at large.

In preparing the present edition for the press, the Publishers have availed themselves of the valuable labours of Mr. Edward Lomax and Mr. Thomas Gunyon, practical Architects and Engineers.

The improvements are rather those of enlargement than of alteration, the greater part of the work being left in its original condition, more especially such parts as related to Carpentry, and subjects of a kindred nature, in which the Author is universally accredited as an authority of the highest standing.

Some parts of the original edition, however, had become obsolete and out of date, and such it was considered advisable to expunge, or modify in such a manner as might make them suitable to the more advanced knowledge of the present day. The articles on Bridges, Strength of Materials, the Orders, and such like, will afford a fair specimen of the treatment of such subjects as required modification or enlargement.

As an illustration of the new matter which has been added, may be particularly enumerated a series of papers treating of the history and characteristics of the various styles of Architecture, which, it is hoped, may prove an interesting and not unuseful feature in the present Dictionary. Besides these, many papers of an Archæological and general, as well as of a practical character, have been added, and a very large number of Definitions introduced, which were not in the original work. Amongst the Archæological papers, those on Church Architecture and Ecclesiology in general, may, it is hoped, be referred to with satisfaction; whilst those of a practical character may be fairly represented by the articles on Roads, Sewers, Cement, &c.

The Plates contained in the original work have also been very carefully compared with the text. Several errors of importance have been corrected, besides a very large number of others of less importance, such as would, however, tend to perplex the student, and even render the information useless to those of more advanced knowledge, who have not the leisure to make the corrections for themselves.

In fine, the Publishers venture to hope, that, while the sterling matter of the original edition is preserved, some Additions and Improvements have been made which may be of service not only to the student and working man, but also to the mature and experienced practitioner; and they flatter themselves that nothing is wanting to render this work, as now presented to the public, containing all the improvements down to the present day, a Complete Architectural Dictionary.

LIST OF PLATES. VOLUME I.

The Plates of each volume are to be found at the end of the book for greater facility of reference. The page, to which reference is made in the following list, is found at the bottom of each page.

LIST OF WORKS CONSULTED IN PREPARING THE PRESENT EDITION OF THE ARCHITECTURAL DICTIONARY.

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Bartholomew's Specifications, 8vo., London, 1846.

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Bingham's (J.) Origines Ecclesiasticæ, or Antiquities of the Christian Church, and other Works, with additional annotations, revised and edited by Rev. R. Bingham, 8vo., London, 1821–9.

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Chambers, Sir W.—A Treatise on the Decorative Part of Civil Architecture, edited by Jos. Gwilt, 8vo., London, 1825.

Chambers, Sir W.—Designs of Chinese Buildings, Furniture, &c., fol., London, 1757.

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A Guide to the Architectural Antiquities in Neighbourhood of Oxford, 8vo., Oxford, 1844–5.

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Prospects of all the Cathedrals and Collegiate Churches of England and Wales, 12mo.

Quarterly Review, Vols. of 1845, 8vo., London, 1845.

The Student's Guide to Measuring and Valuing Artificers' Work, 8vo., London, 1843.

The Builder.

ARCHITECTURAL DICTIONARY.

ABACI, according to Vitruvius, any flat tabulated surface.—The term is applied to the paneis of walls formed in stucco, of which examples may be seen in various remains of antiquity; and to certain decorations of the walls above a part of the podium, or dado.—*Newton's Vitruvius, Chap.* III. and IV. *Book* 7.

ABACUS, (from Greek, *aβaξ*,) the uppermost member of the capital of a column, consisting of a flat, rectangular table contained between two horizontal planes. In all the existing Doric buildings, with perhaps one or two exceptions, it is in the form of a parallelopiped of equal rectangular sides. The same form is preserved in the other orders, but the thickness is considerably diminished. In the Corinthian and Composite, however, the sides are of a curvilinear form in plan. *See* Doric, Ionic, Corinthian, Tuscan, and Composite Orders.

ABBEY, a monastery, or religious house, governed by a superior under the title of Abbot. For a particular account of this species of building, and its distribution, see the article Monastery.

ABBREVIATION, a kind of shorthand, much used by surveyors in measuring work, and greatly facilitating the process. *See* Mensuration *of Artificers' Works*.

ABREUVOIR, or Abrevoir, (from the French,) in masonry the interstice, or joint, between two stones, to be filled up with mortar or cement. *See* Joints.

ABSTRACT, in artificers' works, is used in a general sense, to signify the collecting of sundry articles into one sum, when the same price is affixed to equal parts of each; or, to ascertain measure. *See* Mensuration *of Artificers' Works*.

ABUTMENT, or Butment, that which receives the end of, and gives support to anything having a tendency to spread or thrust outwards:—or it may be defined as the resisting surface of a body, on which another body presses in an oblique direction to the horizon, or in a different direction to the height or length of the body pressed upon; such are the abutments of arches and the joggles of truss-posts, which resist the pressure of the struts or braces. In bridge-building it is the extreme pillars only of one or a series of arches, and thus connects the bridge with the bank of a river, &c. Abutments should be made to resist a greater force than what is just sufficient to balance the abutting works, provided there be no rocks to rest upon. The foundation of an abutment, raised upon a sloping bank of rock, gravel, or good solid earth, will be a great saving of materials and labour; but if no such natural advantages occur, it will add greatly to the strength of the abutment to lay the stones with radiating or summering joints, according to the practice in laying the voussoirs, at least as high as the springing of the arch, and this disposition will present a greater resistance to the lateral thrust of the adjacent arch, than if the stones had been laid on level beds; and instead of the returning sides from the side of the aperture of the arch being vertical planes, they would be much stronger when reclining, and more particularly so if curved in a vertical direction. *See* Bridges and Wall.

Abutments, in carpentry and joinery, are the junctions, or meetings, of two pieces of timber, of which the fibres of the one run perpendicular to the joint, and those of the other parallel to it. M. Perronet, the celebrated French architect, formed the abutments of the timbers, in roofing, in the arches of circles, making the centre in the other extremity. With respect to the tranverse strain on the various pieces of a roof, the abutting joint is of little importance. For farther explanation, *see* Joggle.

ACADEMY, in antiquity, a public grove or villa, six stadia (half-a-mile) distant from Athens, which it is said took its name from one Academus, a citizen of Athens, to whom it originally belonged, and who appropriated it to gymnastic sports.

ACANTHUS, an ornament used in the enrichment of the Corinthian capital, and so called from its resemblance to the leaves of an acanthaceous plant. It is also commonly employed in sculptural and architectural enrichments generally · in the enrichment of modillions, of mouldings, and of vases, as well as of foliated capitals. In the ancient Roman models, this ornament is full and luxuriant; while in the Greek it is characterized by a graceful and restrained simplicity. *See* Orders.

ACCESSES, the passages of communication to the various apartments of a building. *See* Passages.

ACCIDENTAL POINT. *See* Vanishing Point.

ACCOMPANIMENT, an ornament added to some other ornament, for the greater beauty of the work.

ACRE, a quantity of land, containing four square roods, or 160 poles or perches. The acre is in length ten chains, and one in breadth; consequently contains ten square chains; and as the chain contains 22 yards in length, there will be 4840 square yards in the acre. The proportion between the English and Scottish acre, supposing the feet to be alike in both, is as 1089 to 1369, or nearly as four to five; the English chain being 66 feet, and the Scottish 74. The French acre, *arpent*, contains $1\frac{1}{4}$ English acre, or 54,450 square feet.

ACROLINTHON, or ACROLINTHOS, a colossal statue, placed in the temple of Mars, and situated in the middle of the citadel in the ancient town of Halicarnassus.

ACROPOLIS, (from *ακρος*, *height*, and *πολις*, *a city*,) the fortress or citadel of Athens, which derived its name from an eminence on which it stood. The summit is fortified by a wall built on its extreme edge, and encompassing the whole upper surface, which is nearly level. The natural strength of its situation is said to have induced the first inhabitants to settle there, and as their number increased they began to build on the adjacent ground, till the Acropolis, being surrounded on every side, became the fortress of a large and populous city. It was richly adorned by the Athenians, in the days of their prosperity, with temples, statues, paintings, and votive gifts to their divinities. Of this ancient place there are still many fine ruins, some of which are very entire. The remains of the famous Propylea, the little temple of Victory without wings, the Doric temple of Minerva, called the Parthenon, and Hecatompedon, erected in the time of Pericles, under the direction of Phidias, with the cell of Pandrossus, are still to be seen. Its walls have at different times been rudely repaired, or rebuilt, as little of the ancient masonry remains; but numerous fragments of columns, cornices, and sculptures, are seen in several parts, and exhibit a ruinous appearance.

ACROTERIA, a term applied to the little pedestals placed on the pediment or fastigium; one on the apex, and one on each lower extremity, serving to support statues. According to Vitruvius, those at the extremes ought to be half the height of the tympanum, and that in the middle an eighth part more. Acroteria likewise signify figures placed as ornaments or crownings on the tops of temples, or other buildings; they also denote the sharp pinnacles, or spiry battlements, which stand in ranges about flat buildings with rails and balusters, and which are sometimes called acroteral ornaments.

ACT, *Building*. *See* BUILDING ACT.

ACTUS, in building, a measure used by the Romans, and equal to 120 Roman feet. *See* FOOT.

ACUMINATED, ending in a point, or sharp-pointed.

ADIT, or ADITUS, (from *adire*, to go to,) in general, the approach or entrance to anything; in which sense we meet with adit of a house, of a circus, &c. Adits of a theatre, *aditus theatri*, in antiquity, were doors on the stairs, whereby persons entered from the outer porticus, and descended into the seats. The term is now generally applied to denote the opening by which a mine is entered, and which is usually made in the side of a hill.

ADJACENT, anything which lies immediately by the side of another.

ADYTUM, (from *α*, *δυω*,) the most retired place in the pagan temples, into which none but the priests were admitted, and in which the oracles were declared. The word originally signifies *inaccessible*, being compounded of *α*, *not*, and *δυω* or *δυνω*, *to enter*. The *sanctum sanctorum*, or holy of holies, of the temple of Solomon, was of the nature of the pagan *αδυτον*, or *adytum*, none but the high-priest being admitted into it, and that but once a year, on the great day of expiation.

ADZE, an edged tool, the iron part of which is called *the blade*, and is a small portion of a cylindric surface on both sides: it has a piece of wood, called *the handle*, fixed into a socket at one extremity of it, in a radial direction; and the other extremity, parallel to the axis of the cylinder, and consequently at right angles to the handle, is edged with steel, and ground sharp from the concave side. The adze is chiefly used for taking off thin chips of timber or boards, and for paring away certain irregularities which the axe cannot come at; and in most joinings of carpentry, particularly those which are notched upon each other, scarfings, thicknessing of flooring boards opposite to the joists, &c. *See* TOOLS.

ÆDES, in antiquity, a chapel, or inferior kind of temple, as the *agrarium*, or treasury, called *Ædes Saturni*.

ÆDICULA, otherwise called SACELLUM, generally signified a small temple, but had various significations; sometimes denoting the inner part of the temple, in which the altar and statue of the deity were placed; at other times, a niche in the wall, for receiving a statue.

ÆDICULUS, in Roman mythology, the deity who presided over the construction and conservation of buildings.

ÆOLUS, in mechanics, a small portable machine, for refreshing and changing the air in rooms that are too close.

AERIAL PERSPECTIVE, is that which represents bodies diminished and weakened in proportion to their distance from the eye. *Linear* perspective may be considered the material guide of the artist, originating in, and governed by, mathematical science; but *aërial* perspective is dependent for its application only on the capacity and perceptions of the artist.

ÆSTUARY, in the ancient bath, a secret passage from the stove into the chambers.

ÆTHERIUS, an architect, who lived in the beginning of the sixth century. He built the edifice named Chalcis, in the palace of Constantinople; and is supposed to have constructed the strong wall which extends from the sea to Selimbria, for preventing the incursions of the Bulgarians and Scythians.

AGGLUTINATE, to unite one part to another.

AGORA, the forum, or market-place, at Athens.

AGYCI, in antiquity, obelisks sacred to Apollo, and placed in the vestibule of houses.

AISLE, or AILE, (from the French *aîle*, a wing, or *allée*, a path.) When the breadth of a church is divided into three or five parts, by two or four rows of pillars parallel to the sides, the church is denominated a three or five aisled fabric. The middle and principal compartments is called the nave; the side divisions adjoining, the aisles; or, if the term be applied to all the compartments, as it lawfully may be, they are distinguished as the middle and side aisles.

In French, this term is applied to the outlying and returning ends of a building, called by us wings; such as the columned ends of the front of the General Post Office, London.

The ecclesiastical buildings in Great Britain are generally three-aisled; and no instance occurs of a five-aisled church, except a building at the west end of Durham cathedral; but on the continent there are several; the great church at Milan is one. Old St. Peter's, at Rome, was also a five-aisled fabric.

It is rather remarkable, that in Westminster abbey-church, and Redcliffe church, at Bristol, the aisles are continued on each side of the transept, and in Salisbury cathe-

dral on one side only; but in no other church in this country.

Other particulars in connection with Aisle will be found under the articles CHURCH, TRANSEPT, and WING.

ALABASTER. *See* GYPSUM.

ALÆ, two apartments on the right and left of the vestibulum, and separated from it either by columns or walls.

A-LA-GREC, or A-LA-GRECQUE. *See* FRETS.

ALBARIUM, *Opus*, in ancient buildings, the incrustation or covering of the roofs of houses with white plaster, made of mere lime. The workmen were called *albini* or *albarii.* This is otherwise called *opus album*, and differs from *tectorium*, which is a common name given to all roofing or ceiling, including even that formed of lime and sand, or of lime and marble; whereas albarium was restricted to that made of lime alone.

ALCOVE, in a sleeping room, is a recess made in the side for receiving the bed, either wholly or in part. Alcoves were formerly much in use in bedchambers, and were often raised upon two or three steps, with a rail at the foot of the bed; but now they are seldom employed except to obtain uniformity, or a communication to another apartment. The word is derived from the Spanish *alcoba*, and this again from the Arabic *al kubbeh*, the place for the bed.

There is little doubt but the alcoves were of Asiatic or African origin; for we frequently read of them in Arabian stories and descriptions of Asiatic palaces and gardens. They were introduced into Spain, from Arabia, by the Saracens; and by the Spaniards into France, Germany, and other nations. It is remarkable, that in the designs of Palladio and other contemporary Italian writers, there are no examples of alcoves; whence we may reasonably conclude that they had not become fashionable either in Rome or Venice. Swinburn mentions two, yet remaining, in the royal bedchamber of the Moorish palace of Alhambra, at Granada, which are probably the oldest in Europe. The word is also applied to a recess or arched seat in a garden.

ALESSI, a famous architect, born at Perugia, in 1500. He attained to such eminence in his profession, that he was applied to from France, Spain, and Germany, for plans of public buildings. His plan for the monastery of the church of the Escurial was preferred to those of the ablest architects of Europe. He died in 1572.

ALHAMBRA, an ancient palace of the Mohammedan kings of Granada, situated on a hill which runs out to the east of the town, and surrounded by strong walls flanked by square towers. These walls were built of a kind of cement formed of red clay and large pebbles, which, being exposed to the action of the weather, quickly acquired the solidity and hardness of stone.

The beauties of this magnificent specimen of Arabian taste and splendour, have been described at great length by Swinburn and other writers, who express the highest admiration of the exquisite taste displayed throughout the whole.

In visiting the Alhambra, the traveller ascends through a wood of lofty elms, whose interlaced branches shelter him from the sun's rays, to the Gates of Justice, and passes beneath its horse-shoe arch, so characteristic of its Arabian architecture, to the *Plaza de los Algibes*, or Square of Cisterns.

On the east side of this Plaza is the palace of Charles V, a beautiful specimen of the style of the fifth century, by Alonzo Berrequette. On the north is the Mesuar, or common bathing-court, 150 feet long and 56 wide, paved with white marble, and its walls covered with arabesques of the most admirable workmanship.

From the Mesuar the traveller passes to the Court of the Lions, which is also paved with white marble, and measures 100 feet by 60. In the centre is a large basin of alabaster supported by twelve lions, from which rises a smaller one. From this a large body of water spouts into the air, and, falling from one basin to the other, is sent forth through the mouth of the lions. A gallery, supported by light and elegant columns, surrounds the court; and at each end projects a sort of portico or gallery, supported by similar columns.

The Sala de Comares was undoubtedly the richest in the Alhambra. Its walls are ornamented with arabesques of the most exquisite workmanship; its ceiling of cedar-wood, inlaid with ivory, silver, and mother-of-pearl, while the softened light, admitted by windows sunk in the immense thickness of the wall, chastens the splendour of its richness, and enhances its surprising beauty and magnificence.

Lost in the contemplation of the charming objects which surround him on all sides, the traveller forgets the world and its dry realities, and seems transported into one of the palaces described in the "*Arabian Nights.*"

ALIPTERION, (αλειφω, *to anoint*,) the anointing-room in the bath.

ALMS-HOUSE, a small hospital, or edifice, endowed with a revenue for the maintenance of a certain number of poor, aged, or disabled people.

AMBO, or AMBON, in ancient churches, a kind of pulpit or desk, ascended by steps. The modern reading-desks have been gradually substituted for the ancient ambæ: there are, however, remains of them in some Roman churches still to be seen, as in that of St. John de Lateran, at Rome, where there are two movable ambæ.

AMPHIPROSTYLOS or AMPHIPROSTYLE, in ancient architecture, a temple with a portico in front, and another in the rear. The term is derived from αμφ *both*, πρὸ *before*, and ϛυλος *column*, signifying columns on both fronts. *See* TEMPLE.

AMPHITHEATRE, (from αμφι, *around;* and θεατρον, *theatre*,) in Roman antiquity, a large edifice, of an elliptic form, with a series of rising seats or benches disposed around a spacious area, called the *arena*, in which the combats of gladiators, wild beasts, and other sports, were exhibited. It consisted exteriorly of a wall pierced in its circumference by two or more ranges of arcades, and interiorly of vaulted passages radiating from the exterior arcades towards the arena, and several transverse vaulted corridors opening a free communication to the stairs at the ends of the passages, and to every other part of the building; the corridors and ranges of seats forming elliptical figures parallel to the boundary wall.

Sometimes, in the middle of the fabric, there was an intermediate corridor, which, like those on the ground-floor, surrounded the whole, and served as a common landing-place to all the staircases that led to the higher galleries; as in the amphitheatre at Nismes: and sometimes each staircase had its distinct landing, without any gallery of general communication: as in the amphitheatre at Verona.

The four passages in the direction of the greater and lesser axes were generally made wider than the rest, and, by intersecting arched passages, laid open to the adjoining passages on either side of them. The principal entrances, through which the emperor, the senate, and other distinguished persons passed, were placed in the direction of the lesser axes. The other two led directly to the arena by large arched gateways, which were appropriated to the beasts and gladiators. Through the other passages, the different orders of people passed to the staircases, which led to the respective seats. Every arcade around the exterior was numbered, as

well as the divisions, or wedge-formed parts, called *cunei*, which separated the people into different orders.

The amphitheatre was regulated by certain laws, by which each person knew the entry through which he was to pass, to his appropriate seat. The door-ways, which opened from the stairs and passages, were denominated *vomitoria*. The benches, on which the people sat, were about two feet four inches broad, and one foot eight inches high. Before every range of vomitoria, a passage of communication, called a *precinctum*, was formed, about four feet eight inches broad, and bounded on the ascending side by a wall of about three feet four inches high. Surrounding the arena was a platform called the *podium*, which was of greater breadth than the precinctum, and which was defended on the front by strong netting, and rails of iron armed with spikes, and also with strong rollers of timber, which turned vertically, to prevent the hunted animals from leaping over. The emperor's pavilion, called the *suggestum*, was in the podium, at one extremity of the minor axis of the arena, highly decorated, and lined with silk. The seats of the most distinguished persons were also in the podium, and covered with cushions, while marble benches were in general covered with boards; but as the podium was not sufficiently large to contain all the people of high rank, other contiguous places were allotted for that purpose. Over the spectators, in time of rain or intense sunshine, a covering of woollen of different colours, called the *velum*, was occasionally stretched by means of pullies and cords, and drawn up or let down at pleasure.—On the sides of the passages, and under the stairs, on the ground-story, are many cells and rooms, which were probably prisons for criminals condemned to fight or to be devoured, and in which the beasts might be occasionally stabled. It was sometimes the practice to give novelty to the games, by erecting pieces of machinery on the arena, representing mountains, on which real trees were planted, and under them hidden caves were formed, from whence the animals rushed out to encounter the combatants, or to devour their victims.

Amphitheatres are undoubtedly of Roman invention, and were at first constructed of timber; and it was not till the reign of Augustus that one of stone was built by Statilius Taurus, but this does not appear to have been held in much estimation as it was very seldom resorted to. The Roman amphitheatre, called the *Coliseum*, or *Colosseum*, was begun by the emperor Vespasian, and finished by his son Titus, and is deservedly celebrated as a prodigy among the ancients. At the solemn games, when this edifice was dedicated, five thousand wild beasts, according to Eutropius, and nine thousand, according to Dio, were destroyed on its arena. When the hunting was concluded, the arena was suddenly filled with water, in which aquatic animals were made to contend, and then a sea-fight ensued. According to Tappen, the greater axis of the ellipsis of this stupendous edifice was 627 feet, and the lesser, 520. According to Desgodetz, the height of the exterior wall was 156 feet, the greater axis of the arena about 264 feet, and the lesser 165 feet; therefore the medium breadth of the circuit, for seats, galleries, and wall, was about 179 or 180 feet.—This edifice covered something more than five acres of ground.

The boundary wall was pierced by five ranges of apertures, of which the three lower were arcades, having eighty openings in each range, and the upper two rectangular windows. Its exterior side was decorated with orders, in four ranges, with continued entablatures; the three lower were colonnades, and the upper a pilastrade.

The lowest order was Doric, without mutules, triglyphs, and guttæ; but the shafts of the columns terminated with bases: the second was Ionic, with the Attic base; its volutes were slightly formed, and the dentil band uncut: the third and fourth orders were Corinthian, with unraffled leaves. The diameter of the columns, in the several ranges, was two feet eight inches and three quarters, as also the breadth of the pilasters; the columns of the lower range were twenty-six feet high, and each of the others twenty-four feet only. This makes the Doric columns higher than either the Ionic or Corinthian, and the altitude of the Ionic and Corinthian equal to each other, while all the columns have equal diameters, and are of the same breadth with the pilasters of the upper range. The sima of the cornice of the lower Corinthian was supported by modillions, without the intervention of the corona, and the column has a Tuscan base. The upper Corinthian had its cornice formed in front by three faces, and a cymatium like an architrave, and supported by cantalivers, projecting out of the frieze; or the entablature may be looked upon as an architrave cornice, reckoning the frieze and cantalivers a part of it. The whole edifice was crowned with a blocking course.

The first colonnade was raised on several steps, about three feet two inches above ground, and the bases of the columns stood on the uppermost step, which formed the pavement of the entrances. In the superior stories, the piers and columns were elevated on stylobatæ and podia, and the second and third ranges of arcades stood upon podia also. The boundary wall was diminished upwards in its thickness on both sides, but more particularly from the exterior side of it, in each succeeding story, and the columns of the two lower ranges projected three quarters of their diameter, while those of the third range did not project more than the half; and therefore the axes of the columns of each succeeding range upwards, were more recessed than those of the inferior range. This recession is more observable in the upper range of columns than in that immediately below; but still more in the pilasters of the third order. The diminution of the columns commences from the third part of their height. The straight soffits of the fillets and other horizontal projections rise more in the front than in the rear. The lower range of the rectangular windows had one window disposed in every alternate podium, below the upper order; and had the upper range of windows in the inter-pilasters above the imperforated podia. The cornice of the uppermost order was pierced with square mortises, through which the awning poles passed to a range of corbels below, something higher than the middle of the pilasters. Seventy-six of the lower range of arcades were about thirteen feet four inches broad, and the four placed upon the extremities of the axes, about fourteen feet six inches. The lowest range of arcades radiated vault-wise towards the arena, in a direction almost at right angles to the curve of the plan of the exterior wall, and intersecting two vaulted corridors, passed on to the staircases in the same direction. Two other corridors were placed between these stairs and the wall of the podium, and other stairs between the second and fourth corridors. The first staircases were entered by the second and third corridors, and those next to the arena by the third corridor only; this corridor was lighted from above, by vertical square holes, descending through the crown of the vault; and, it is probable, that the fourth corridor, adjoining the wall of the podium, was lighted in the same manner. The second story had three corridors, laid open to one another by radiating passages: the first two were placed over the first and second corridors on the ground-floor, and between the second and third were placed stairs, which ascended on the one hand to the second range of vomitoria, and on the other, to another high-groined corridor, forming a mezzanine, which was

lighted from the floor of the gallery above, and from which the stairs ascended to the next story. The third story consisted of a double corridor, from which the stairs continued upwards to the fourth galleries, the interior wall of which was pierced with windows and doors, or vomitoria, that opened to the uppermost cunei of benches. On the inside of the exterior wall are vestiges of stairs which led to a fifth gallery; this again had four staircases, which led to a sixth gallery; and from thence the stairs continued to the top. The two upper floors were contained in the height of the pilastrade.

The stone employed in this edifice is the produce of the neighbourhood of Rome, and is called *Travertine-stone*, of which the exterior walls, the piers between the two outer corridors, the heads of the passages and corridors, and some bendstones, are constructed: all the rest is of brick. The exterior wall is cramped with ligatures of iron, without cement; some of the internal walls have remains of plaster ornaments, and others are lined with marble. The floors of the corridors are paved with flat bricks, and covered with a hard incrustation of stucco. This building is supposed to have contained 100,000 persons; but it will be found that by allowing two feet two inches from seat to seat, and one foot nine inches to the breadth of each person, not more than 80,000 could be accommodated, even supposing all the upper galleries to be filled.

"The proportions of this edifice," says Tappen, "were in such perfect harmony with each other, that there was nothing gigantic in its appearance, although the greatness of its dimensions never fails to impress every mind with ideas of its sublimity."

A structure of such dimensions, and of such contrivance and ingenuity as the Colosseum, eclipses the most magnificent works of the Egyptians and Greeks, and even those of modern times. The structures of Egypt, such as we may conjecture from what now remains, have little to recommend them, except their magnitude and the enormous stones employed in their construction. For beautiful simplicity, and chastity of parts, the Greeks excelled every other people; yet the Romans, though licentious in the detail and embellishments, showed much ingenuity, not only in the arrangement of their plans, but in the construction of the elevated parts, both with regard to the solidity of the work, and the end to be answered by the design. Our finest embellishments and best proportions are of Greek origin; but the Romans have set us the example in a beautiful diversification of plans.

The Amphitheatre at Verona consisted, formerly, of three stories of arcades, with pilasters against the piers of each story, bearing continued entablatures. The pilasters and arches are all rusticated and unwrought on the face. The orders which decorate the solid parts of the masonry are of no legitimate species, but more nearly allied to the Tuscan than any of the other three. The second pilastrade stands upon a plinth, and the third upon a triple plinth. The pilasters of the first and second ranges are very slender, particularly the second; those of the third range are double the breadth of those of the second range, contrary to the laws of strength.

The arches forming the heads of the first and second arcades are extradossed, and project out beyond the rustics, which form the horizontal courses above; the arches forming the heads of the third arcades are also extradossed, but each has another concentric extradossed arch, springing on each side from the pilaster, with its face in the same plane with the pilasters, and its inner diameter equal to the clear distance of the pilasters. The edifice is finished with a blocking course, resting upon the upper entablature: of the outer wall only a small part remains. From some mutilated courses of rustic work, and the lower part of two plain pilasters which remain, it has been supposed that the building had also a fourth story. The height of the three existing stories is about 90 English feet. This edifice was erected without cement; the stones being nicely joined with cramps of iron, covered with lead. The greater axis of the ellipsis of the plan, according to Desgodetz, is 433 feet 8 inches, and the lesser 333 feet 4 inches; the greater axis of the arena 237 feet, and that of the lesser 136 feet 8 inches; the breadth, for benches and wall, being 100 feet 4 inches; each range of arches were seventy-two in number, which opening into the first range of arcades, radiated towards the arena, in passages and staircases, crossing a corridor surrounding the whole; the passages, proceeding forward, crossed two other surrounding corridors, between which were other stairs.

The second story has one corridor above the exterior lower one. Above are forty-six tiers of seats, rising by equal degrees from the arena to the wall upwards. The interior of this edifice is entire, having been wholly reinstated by the inhabitants, from time to time, for the purpose of exhibiting plays, and other diversions.

The greatest diameter of the ellipsis of the Amphitheatre at Nismes is 430 feet, and the least 338 feet; the whole height 76 feet 6 inches.

The elevation consisted of two stories of open arcades and an attic. Each story had sixty arcades in its circumference, of which the four placed upon the extremities of the axes form the grand entrances, and are decorated with pediments. Against the solid parts of the masonry are Tuscan pilasters, resting on pedestals, and supporting an entablature which breaks over them. On the top are short, hollowed stone corbels, in which, it is supposed, poles were placed, for bearing an awning over the spectators. Many of the rows of seats are entire.

The remains of the Amphitheatre at Pola, in Istria, consist of an elliptic wall, pierced around its circumference with 72 arches; containing two stories on one side, and one on the other, being built on the side of a hill. Above the upper arcade is an attic, pierced by 72 square-headed windows, which surround the whole: through this are grooves for the poles that supported the velum. The greatest diameter of the ellipsis is 416, and the least 337 feet.

The Romans constructed Amphitheatres in England; one at Dorchester, and one at Ilchester.

AMPHITHURA, (from the Greek, *αμφιθυρα, both doors,*) in ecclesiastical antiquity, the veil or curtain which divided the chancel from the rest of the church; so called on account of its opening in the middle, after the manner of folding doors.

ANABATHRUM, (from *αναβαινω, I ascend,*) a kind of ladder, or steps, by which an eminence may be ascended. In this sense, we read of the anabathra of theatres, pulpits, &c.

ANAGLYPHICE, or ANAGLYPTICE, (from *ανα, γλυφω, to carve* or *engrave,*) a species of sculpture wherein the strokes of the figures are prominent or embossed: in opposition to the *Diaglyphice*, where the strokes are indented.

ANAMORPHOSIS, (*ανα μορφη,*) in Perspective and Painting, a monstrous projection, or a representation of some image, either on a plane or curved surface, deformed or distorted, but which, in a certain point of view, appears regular and in just proportion.

ANCHOR, an ornament in form of an anchor, or arrow's head, employed in the echinus, or ovolo, between the borders which surround the eggs. This anchor, with its concomitants, are generally carved on the ovolo of the Ionic capital;

and in the Grecian, Ionic, and Corinthian orders, upon all large mouldings of this form: they are not employed in the Grecian Doric, though they are used in the Trajan and Antonine columns of the Tuscan order, at Rome.

ANCONES, the trusses or consoles sometimes employed in the dressings of apertures, as an apparent support to the cornice, upon the flanks of the architrave. In many ancient doors, the ancones were narrower at the bottom than at the top, and, in some instances, were not in contact with the flanks of the architrave, but placed at a small distance from them; the ancones being further separated from each other. Vitruvius calls them *prothyrides*.

ANDREA DE PISA, a sculptor and architect, born at Pisa, in 1270. He built several castles, and the church of St. John, at Pistoia; but his skill in architecture was principally displayed at Florence, where he erected many mansions, enlarged and fortified the palace of the duke, and surrounded it with magnificent towers and gates. On account of these works, he obtained the right of citizenship. At the request of the duke of Athens, he made a model of a citadel, which he intended to erect for restraining the Florentines. On this account, they took the alarm, and expelled the duke; but Andrea passed the remainder of his days at Florence, cultivating the fine arts, such as painting, poetry, and music, besides those which were professedly his own. He died in 1345, aged 75.

ANDRON, or ANDRONA, (from *ανηρ, a man*,) in antiquity, an apartment in houses, assigned to the use of men. It was sometimes called *andronitis*, in opposition to *gynecæum*, the apartment appropriated to the use of women. The Greeks also gave their dining-rooms the title of andron, because the women were not admitted to feasts in company with the men. Androna, in ancient writers, denotes a public place where people met to converse on business, such as our exchanges; however, it is more particularly used to signify the space or alley between two houses; and in this sense it was used by the Greeks, for the passage between two apartments in a house. This word is sometimes written, *andra*, *andrion*, or *andronium*, and is of the same import as the Roman term *mesaulæ*.

ANGLE, *rectilinear*, (Lat. *angulus*, the elbow,) according to Euclid, "the inclination of two straight lines to one another, which meet, but are not in the same direction." This definition, if indeed it may be termed such, is so very indistinct, and even inaccurate, that it has been entirely discarded by modern mathematicians, who have individually given many suggestions for its improvement, but have not agreed so far as to adopt any as a standard definition. We give the following as one of the most correct:—"An angle is the ratio of the plane surface bounded by two infinite right lines which meet, to the plane surface on all sides indefinitely extended about the point where they meet." Thus the A B C is the ratio of the plane surface, bounded by the straight lines A B, B C infinitely extended to the unbounded plane of the paper about the point B. Objections, doubtless, may be urged against this, as against all other suggestions; but the subject is unquestionably a difficult one, as it necessarily involves the long-disputed question concerning infinite magnitudes. The following description, though not amounting in preciseness to a definition, affords a very intelligible notion of the idea intended to be conveyed by the term, viz: the opening made by two intersecting right lines.

Comparison of Angles. As every theory respecting the comparison of infinite spaces is attended with considerable difficulty, we shall leave the consideration of the more abstruse points of this subject to works of a different nature, and endeavour to explain, as clearly as possible, the method of comparing angles.

Let A B C, D E F, (see the plate) be two angles formed by the intersection of the straight lines A B, B C, D E, E F, at the points B E, respectively.

Apply the angle A B C to angle D E F in such a manner, that the points B E, and the lines B C, E F coincide, then the position of E D with respect to B A is determined. Such being the position of the two figures, if E D fall upon B A, the two openings coincide, or, in other words, the angle A B C is equal to the angle D E F. If, however, E D fall between B C and B A, the opening or angle D E F is less than the other A B C; if, on the other hand, E D fall without or beyond B A, the angle D E F is said to be greater than the angle A B C.

Again, supposing the angles to be applied as before, and E D to fall within A B; let E D remain fixed in that position, but let E F be turned about E D as an axis, until it fall on the opposite side of it; then, if E F coincide with B A, it is evident that the angle A B C is equal to twice the angle D E F. In the same manner may be explained the notion of one angle being three, four, or any number of times greater or less than another.

It may be necessary to observe, that the magnitude of the angle in no wise depends upon the length of the intersecting lines; for, if we suppose a part D *d* to be cut off from the side D E, upon applying the angle D E F to angle A B C, as above, we shall find that the line E *d* will still fall in the same position with respect to A B, as it did before D *d* was cut off; and will do so, however short E D may become, until the line, and therefore the angle, ceases to exist.

Again, let us suppose a line starting from a certain station A B, to revolve round one of its extremities A as a fixed point or axis, and to arrive at the situation A B_1; it will then, with its original position, describe an angle B A B_1. Let it now continue its revolution, until it has passed over another space equal to the preceding, and in so doing has reached the position A B_2; it will then be readily understood that the angle B A B_2 equals twice the angle B A B, and thus we might describe an angle any number of times greater than B A B.

Euclid's notion of an angle has been very much enlarged upon by later mathematicians, as we proceed to illustrate by reference to the last diagram. Let us conceive the line A B to continue its revolution to B_3, and thence to B_4; we say then that A B_4 forms with its first position the angle B A B_4, and thus far Euclid allows; but if the revolution be continued until A B arrives in the position A B_5, so as to form a straight line with its first position—which event takes place when it has performed half a revolution—Euclid no longer recognizes the opening so formed as an angle. Such, however, it is reckoned to be by the moderns, and that not without reason; for it will be readily acknowledged that the opening formed by the lines A B and A B_5, is greater than that formed by A B and A B_4, thus showing that such opening is liable to comparison in the same manner as any other angle. The same reasoning will apply to openings formed by a whole revolution or more; indeed, the moderns do not restrict the term to any number of revolutions however great.

A RIGHT ANGLE is that traced out by A B while performing a quarter revolution.

AN OBTUSE ANGLE is that which is greater than one right angle, and less than two.

AN ACUTE ANGLE is that which is less than one right angle. The angle formed when A B has completed one revolution and arrived at A B, is described as four right angles + angle B A B.

Measurement of Angles. Referring again to the last diagram, it will be seen that the point B in the line A B, during its revolution round its axis A, describes a circle. Now the circumference of any circle so described is supposed to be divided into 360 equal parts, called degrees, each of such degrees into 60 minutes, and each minute into 60 seconds. This division is made use of for the measurement of angles in the following manner :—As the angle traced out by a whole revolution passes over in its progress 360 of the larger divisions, it is styled the angle of 360 degrees; similarly, the right angle, which makes only a quarter revolution, is named the angle of 90 degrees; and so on for angles of any dimensions whatsoever.

The measure of the arc is sometimes used indiscriminately for that of the angle; but such measurement is, strictly speaking, incorrect. *See* ARC.

External ANGLE, in civil architecture, the same as *Saliant* ANGLE, which see.

Internal ANGLE, in civil architecture, the same as *Re-entering* ANGLE, which see.

Re-entering, or *Re-entrant* ANGLE OF A SOLID; an angle whose vertex recedes, or is turned inwards, from a right line extended between any two points in the legs; or it is a cavity or void, formed by two planes on the surface of the solid. Artificers call all such angles, made by walls or partitions, *Internal Angles.*

Saliant or *Sortant* ANGLE OF A SOLID, an angle, of which the vertex is prominent; or it is the solid matter contained between two planes inclined to each other in an angle less than two right angles; or, it is such, that if a point be taken in each plane, the straight line joining the two points, will pass through the solidity. Artificers call all such angles, made by walls or partitions, *External Angles.*

Solid ANGLE, the mutual inclination of more than two plane rectilineal angles meeting in a point, and not contained in the same plane.

ANGLE OF A WALL, the angle contained by the two vertical planes which form the angle of a building. It would be better denominated *the angle of a building*, a term sufficiently explanatory of itself; but as it is to be found in other dictionaries of this nature, it is here inserted. The angle of a wall is said to be "the point where the two sides meet;" but it should be *the line where the two sides meet*, which is commonly called by workmen the *arris;* still the arris is not the angle, but the line of concourse formed by the two sides, or planes, containing the angle.

ANGLE BAR, in joinery. When a projecting window stands on a polygonal plan, the upright bar at the meeting of any two planes of the sides of the window is called an *angle bar.* When there are mouldings on the other bars, the angle bars should be made to mitre with the horizontal bars on either side of them. The manner of finding the section of an angle bar, is shown under the term *Raking* MOULDINGS.

ANGLE BRACES; when a quadrangular frame has a timber opposite each angle, fixed to each of the two sides forming the angle, and thereby making the inside of the frame of an octagonal figure, the timbers so fixed, are called *angle-braces*, or *diagonal ties*, or *angle ties;* the angles of wall-plates are frequently braced in this manner. Also when a well-hole, of a circular section, is made through a roof or floor, for a sky-light, &c., the framing is first made quadrangularly; then braces are fixed opposite to each angle, and the aperture becomes an octagon; and lastly, pieces are again fixed in each angle of the octagon, meeting each other in the middle of its sides, so as to transform the section of the aperture into a circle, and thus the well-hole is shaped as required.

ANGLE BRACKET. *See* BRACKETING.

ANGLE RAFTER. *See Hipped* ROOF.

ANGLE RIB, a curved piece of timber, placed between those two parts of a coved or arched ceiling, or vault, which form an angle with each other, so as to range with the common ribs on each side, or return part. Examples will be seen under the articles DOME, GROIN, and *Hipped* ROOF.

ANGLE-STAFFS, or STAFF-BEADS, vertical beads, generally of wood, fixed to exterior angles, flush with the intended surface of the plaster, on both sides, for the purpose of fortifying the angles against accident: they serve also for floating the plaster. Their section is about three-fourths of a circle, with a projecting part from the other quarter, by which they are fastened to the wood bricks, plugging, or bond-timbers. The section of angle-staffs is sometimes that of a triple bead, the middle one being larger than that on either side of it, and flush with it and the plaster. Angle-beads of wood, around the intradosses of circular arches, are difficult to bend without cutting or steaming them; the former has a very unsightly appearance, and the latter is both inconvenient and troublesome: for this situation of angle-beads, no other material will finish better than the plaster itself; and it will be sufficiently strong, as at that height it is more out of the reach of accident. Whenever wooden and plaster beads are employed in the same margin, or angle, they should never join each other, but should always have an impost to intervene, as, otherwise the joint will show. In grand finishings no corner beads are employed; but the plaster is well gauged, and brought to an arris.

ANGLE TIES. *See* ANGLE BRACES.

ANGULAR, something relating to angle.

ANGULAR CAPITAL, is generally applied to the Scammozzian, or modern Ionic capital, which is formed alike on all the four faces, so as to return at the angles of the building, as in the Temple of Concord. It is also applied to those capitals of Grecian edifices which had two fronts alike on each angle of the building, in order to face the front and flank alike, and to correspond to the other capitals, upon the columns ranged in the flank, as well as in the front. *See* PLATE.

ANGULAR CHIMNEY, one which stands in the angle of an apartment, with the plane of its breast intersecting the adjacent walls. For the method of measuring angular chimneys, see CHIMNEY.

ANGULAR MODILLIONS, those which are placed at the return of a cornice, in the diagonal vertical plane, passing through the angle or mitre of the cornice.

As angular modillions are not to be traced among the ruins of Grecian edifices, it may be concluded, that they were seldom or never used by the Greeks; nor are they to be found among the ruined edifices of ancient Rome; it is however probable, that they may have been used in the decline of the empire, since they are to be seen in the remains of the palace of the emperor Diocletian, at Spalatro, in the vestibulum, and in the temples of Jupiter and Æsculapius. The ruined cities of Balbec and Palmyra exhibit many specimens, in the large porticos, and in the entablatures of doorways.

ANGULAR VAULT, a vault supported upon two circular walls; such as the temple of Bacchus, at Rome; the Temple church, London; the church of the Holy Sepulchre, at Cambridge, &c.

ANNULETS, (from the Latin, *annulus*, a ring,) the annular fillets between the hypotrachelion and echinus of the Doric capital. In the Roman Doric, they are generally three in number, and of equal size, with rectangular sections. One side of each annulet is a horizontal soffit, seen from below, the other is a vertical cylindrical surface, having the same

axis with the column, the projection of each soffit being equal to the height of its respective vertical side. In the axisal section of the Grecian Doric, except in the case of the Doric portico at Athens, the number of annulets vary from three to five; the sinkings between each two follow the line of the echinus, and the outer sides of the fillets form a curve parallel to that of the sinkings; the upper side of each is perpendicular to the curve, and the lower side is concave towards the space between each two: the concavity begins in a direction perpendicular to the curve of the moulding; the flutings of the shaft of the column terminate under the lowest annulets. There are also other names by which an annulet is sometimes called, as *cincture*, *fillet*, and *list*, or *listella*, which are equally applicable to rectilineal members, and therefore should never be used but in a general description, where there is some common property to be explained, as they do not particularly imply circularity.

ANNULUS, a Cylindrical Ring, a solid formed by the resolution of a circle about a straight line without the circumference as an axis, and in the plane of the circle. For the method of measuring an annulus, see MENSURATION.

ANTÆ. When the two parallel side-walls or flanks of a temple. or other edifice, are protruded or lengthened out beyond the end of the building, and when each of the two projections is covered with a vertical body, projecting on each side of the thickness of the wall, having a base, a prismatic trunk, and a capital, similar to a pilaster; then these bodies, or terminations, are called *antæ*. The breadth of the antæ on the flanks of the temple was always less than in the front; and the two edges of the antæ which faced each other within, and on the sides of the pronaos, were equal to the diameter of the columns placed between them, while that of the opposite, or outsides of the flanks of the edifice, was much less. The capitals of the antæ never corresponded with those of the columns, though the mouldings were more or less enriched, as the order had more or fewer decorations. In the temple of Minerva Pollias, and the temple of Apollo Didymæus, in Ionia, the capitals of the antæ have a strong resemblance to those of the columns; they having also volutes, though not of the same proportion, nor depending in the same way; as these are hung to an upright, and those to a horizontal hem, connecting the two. Antæ differ from pilasters, not only in their capitals, but also in their situation. A portico is said to be "in antis" when columns are placed between the two antæ. *See* TEMPLE.

ANTECHAMBER, (from the Latin, *ante*, before, and *camera*, a chamber,) an outer chamber, before a principal one, where servants wait, and strangers are detained till the person to be spoken with is at leisure.

ANTEFIXÆ, blocks with vertical faces placed at regular intervals on the uppermost member of a cornice, for the purpose of hiding the ends of the covering or joint-tiles of the roof. The faces of antefixæ are usually carved with some ornamental device, as a flower, leaf, &c.

ANTEMURAL, (from *ante*, before, and *murus*, a wall,) an outer wall, environing the works and walls of a fortified place, in order to prevent the enemy from approaching too near. In some writings, it signifies the same as an outwork.

ANTEPAGMENTA, or ANTIPAGMENTS, (from Greek *αντι*, *πηγνυμι*, *to fix*,) in ancient architecture, the jambs of a door moulded like an architrave. The lintel returning at the ends, with similar mouldings, down upon the antipagmenta, was called the *supercilium*. Also carved ornaments of men, animals, &c., placed on the architrave.

ANTERIDES, in ancient architecture, the buttresses erected to strengthen a wall: they are called in Greek, *ερεισματα*, and answer to what our modern builders call *counter-forts*, and *archbutants*; by the Italians they are called *barbicane*, and *speroni*, or *spurs*. They are also sometimes called *antes*, sometimes *crismæ*.

ANTE-ROOM, a room through which a person must pass, in order to enter into another room. In many constructions of houses, there is a necessity for introducing ante-rooms, from the peculiar arrangement of the plan; and in many situations, besides being useful, they add both grandeur and elegance to the design.

ANTES. *See* ANTÆ.

ANTHEMIUS, a distinguished architect, a native of Tralles, in Asia Minor, and employed by the emperor Justinian in the construction of various edifices, particularly the church of St. Sophia, at Constantinople, which he designed, and also superintended 10,000 workmen in its execution. Anthemius was also a sculptor, a mathematician, and an experimental philosopher.

ANTICS, figures of men, beasts, &c., placed as ornaments to a building.

ANTICUM, the porch before a door; also, that part of the temple which is called the outer temple, and lies between the body of the temple, and the portico.

ANTIPORTICO, a word sometimes used to denote a vestibule, or porch, at the entrance of an edifice.

ANTIQUARIUM, among the ancients, an apartment in which their antique monuments were preserved.

ANTIQUE, in a general sense, denotes something ancient; but the term is chiefly employed by architects, sculptors, and painters, and applied to works, in their respective professions, executed by the Romans, or others anterior to their time; such as the Colosseum at Rome, the temple of Minerva at Athens, &c.

ANTIQUES, a mixed composition of the effigies of men, inferior animals, utensils, and implements of war, with foliage, flowers, and fanciful ornaments. The ornaments on the walls of the Vatican, at Rome, painted by Raphael, are of this kind, and were imitated from the grottos of the baths of Titus, of which there were ample remains in his time. This species of decoration is frequently called *arabesque*, or *grotesque*; the latter is the more correct appellation, as the former applies solely to Arabian ornaments, which consisted of foliages and fruit, without any animal representations.

ANTIS. *See* TEMPLES, ANTÆ.

ANTISTATES, one of the architects employed in raising the foundation of the temple of Jupiter Olympus, at Athens.

ANTONINE COLUMN, a pillar of the Tuscan order, erected in Rome, by order of the senate, to the memory of the emperor Antoninus. It is 175 feet in height, *viz.*, 168 feet above ground, and 7 feet beneath the surface; and has a winding staircase, with 198 steps in the ascent, and 56 windows, or loop-holes. The sculpture, and other parts, are similar to those of Trajan's column, but the work is greatly inferior. *See* COLUMN.

APART, the distance between the nearest surfaces of any two bodies. This term is much used in building, particularly in the art of carpentry; as, joists are placed from eleven to twelve inches *apart*.

APARTMENT, any part of a house that is walled round, and that may be entered through doors; as kitchen, vestibule, saloon, dining-room, drawing-room, chamber, closet, library, passage, &c. All the apartments, on the same floor, taken collectively, when opening one into another, without an intermediate passage, are called a suite of apartments.

The word apartment may also denote a portion of a large house, wherein a person may lodge separately, having all the conveniences requisite to make a complete habitation.

A complete apartment is said to consist of a hall, a chamber, an ante-chamber, a closet, and a cabinet, or ward-robe.

When an apartment has one or more of its sides contiguous to one or more of the exterior walls, and has no other apartment above, it may be lighted either through apertures in the vertical sides of the exterior walls, or by a skylight, as may be found most eligible.

When an apartment is contiguous to one or more sides of the building, but has one or more apartments above, it becomes necessary to light it from apertures in the external walls. Dining-rooms, withdrawing-rooms, and bed-chambers, are more conveniently and agreeably lighted from the exterior walls, than from the roof.

When an apartment is surrounded on all sides by other apartments, but has no other above, it may be lighted by a skylight; or, if its height exceed the height of the adjoining apartments, it may be lighted from windows in the sides, above the roofs of the surrounding apartments. A saloon, a staircase, or a dome, is more elegantly lighted in this manner, than in any other.

When several contiguous apartments, above each other, are surrounded on the sides, they may either be lighted horizontally through the sides by borrowed lights, or vertically, through apertures in the several ceilings and the roof. Sometimes the situation of passages renders it necessary to light them in the latter method, by forming apertures through the several ceilings and the roof, over each other, with a skylight at the top, and rails round the openings in the floor. Granaries and warehouses, consisting of several stories, and surrounded with buildings, cannot be lighted in any other way, than from skylights in the roof, and apertures through the several floors, vertically over each other. To save room, the space allotted for the passages, upon each floor, may be directed across the openings, and the openings may be ribbed or latticed with strong bars, for walking upon.

The method of proportioning and finding the number of apertures for lighting an apartment or room, will be seen under the article WINDOWS; and the proportion of chimneys to the cubature or sides of apartments, is shown under the article CHIMNEYS.

What relates to the ceilings of apartments, will be found under the articles, CEILINGS, COMPARTMENT CEILINGS, and VAULTS.

The proportions of apartments depend much on their use. The length of rooms may be extended from once to twice the breadth, and galleries even to three or four times. It is, however, to be observed in general, that the greater the cubature of the room, the greater also must be the ratio of the dimensions of the plan. Thus the dining-room, or withdrawing-room, in a very small house, may be square, but that in a large edifice may be a double square, or less, according as the disposition of the plan of the building may turn out; the length of the largest rooms should, however, never be less than once and one-third of their breadth. As to the height, it may be three-fourths of the breadth, when the ceiling is flat and equal to the breadth, or once and one-fourth of the breadth, when the ceiling is covered or arched, according to the rise of the arch. It may be thought, that there might be some ratio between the height and length, but this idea vanishes when it is considered, that the eye can only take in a certain portion of the length, and therefore the comparison must be made with the breadth.

If the apartment be a principal passage, its breadth may be one-third of the breadth of the principal room; and if it be a by-passage, or that of a very common house, its breadth may be one-fourth of the breadth of the principal room: the height is the height of a story; but the length is indefinite.

With respect to the staircase apartment, the area occupied by the floor depends on the height of the story, the rise and tread of the steps, the formation of the plan, the number of quarter or half paces, and the size of the passage, or lobby, at the beginning or landing; also whether the stair be made single or double; or whether it consist of one or two revolutions in the height of the story. The proportion of the dimensions of the plan of the staircase depends on the proportion of the individual dimensions of each apartment, the proportion of the area of the plans to one another, and their disposition. A principal staircase should never consist of two revolutions. The more of an oblong the plan of a staircase is, the less room will be required, provided the going of the steps be placed in the breadth, and that each flight on the opposite side consist of an equal number of steps, connected by windows, between the flights; since by such means the lobby and landing above are shortened, and also less room is occupied by the newal. What further relates to staircases, will be seen under the article STAIRS.

To preserve the best possible proportions in a floor of apartments, the principal rooms may have flat ceilings; the middle-sized ones may have their altitudes reduced by introducing cove and flat ceilings, cylindrical vaults, domes, groins, &c., as may be most suitable to their heights; and the smallest rooms may have mezzanines over them, wherever they are accessible to back stairs; but when the disparity is great between the height of the principal rooms, and those of the middle size, the whole of the rooms in the suite, except the principal ones, may have mezzanines above; the middle-sized rooms may have flat ceilings; and the smaller rooms arched ceilings. Mezzanine apartments are not only necessary on this account, but they may be employed with great advantage, since they afford servants' lodgings, baths, wardrobes, &c.

In buildings where beauty and magnificence are preferred to economy, the halls and galleries may be raised to the height of two stories. Saloons are most frequently raised the whole height of the building, and have galleries at the height of the stories, around their interior circumference, communicating with the various apartments. In general the area occupied by the saloon, may be half of that occupied by the dining-room, drawing-room, or principal-room.

The walls of apartments may be ornamented with columns, pilasters, entablatures, niches, recesses, panels, &c., as also with foliated and other enrichments.

When an apartment is adorned with an entire order, the entablature may occupy from one-sixth to one-seventh part of the height of the order, or of the room itself, when the ceiling is flat. If a cornice, frieze, and astragal are executed, instead of the full entablature, their height may be equal to one-tenth. If a cornice only is executed, its height may be one-twentieth or one-thirtieth part of the height of the room. In general, all interior proportions and decorations should be smaller and more delicate than those of the exterior: pilasters should not project more than one-eighth, or one-tenth of their breadth; and architraves round apertures should, in most cases, not exceed one-seventh of the openings. When the sides of rooms are straight, and are adorned with columns or pilasters ranged the whole length of each side, the columns or pilasters may be either single or coupled, as the piers of the windows may admit: if each extreme pier be equal to, or more than the half of each intermediate pier, the columns or pilasters may be placed single, or in couples, as the breadth of the intermediate piers may allow; but if each extreme pier, or one only of them, be less than the half

of each intermediate pier, it will then be necessary to couple the pilasters. If one of the extreme piers is greater than the other, the former may be made equal by forming the end of the room cylindrical; if each extreme pier exceed the breadth of each intermediate pier considerably, then both ends may be formed into cylindrical surfaces, or otherwise columns may be introduced at each end, and the entablature continued over the columns; the recesses also may be adorned in a different manner, or one of the ends may be made cylindrical, and the other colonnaded.

Apartments of a quadrangular plan are either constructed so as to have the same symmetry on the opposite sides; or to have no corresponding symmetry whatever, on either pair of these sides. When bows are introduced into apartments, they are generally at the ends; but if upon one or both sides, they should be proportioned to the length. Sometimes, in very large apartments, with a fireplace at each end, two bows are introduced.

In the best houses, kitchens, halls, servants' rooms, and water-closets, are frequently wainscoted to the height of about four and a half feet, and coped with a neat moulding, which is generally a bead.

Halls, passages, staircases, and bedrooms, have frequently bases without dado, or surbases. Principal rooms have always complete pedestals. Apartments laid with stone-pavements, should have stone plinths, with wooden bases.

All further information respecting the finishing of apartments, will be found under the heads, CEILINGS, COMPARTMENT CEILINGS, VAULTS, DOORS, WINDOWS; and other particulars relating to distribution will be found in the article DESIGNING.

APERTURE, an opening through a body. An aperture in a wall has generally three straight sides, two of which are perpendicular to the horizon, and the third parallel to it, connecting the lower ends of the vertical ones. The stones forming the perpendicular sides are called *jambs*, the level side below is called the *sill*, and the upper part is called the *head*. The head of an aperture is either an arch, or a single stone, or beam.

Apertures are either made for entrance, light, or ornament. *See* DOOR, RECESS, and WINDOW.

A narrow aperture may be covered with a single stone, to such horizontal dimensions as may be found convenient to raise from the quarry.

When the aperture is wide, stones in separate pieces may be joggled together, in order to form a *straight arch*, as it is absurdly called by workmen; or the same kind of arch may be made with radiating joints concealed within the thickness of the wall, and vertical joints on the front, secured by strings or cramps of iron, if necessary; when an aperture is very wide, it becomes necessary to arch it over.

Too great a variety of apertures in the same front of a building destroys its uniformity.

The ancient Greeks and Romans made the sides of apertures frequently incline toward each other at the top.

Apertures are sometimes made quite circular or elliptical; but these forms are not in general use. In apertures of stone-work, if the jambs be of one entire piece, every alternate stone in the height of the aperture, next to the jambs, should be bond-stones; likewise, if the jambs consist of several stones in the height, every alternate jamb-stone should be a bond-stone. *See* STONE WALLS and WINDOWS, in MASONRY.

When the heads of apertures are arched, they require to be supported on *centres* while building; the method of constructing which is shown under the article CENTRE.

APEX, the highest point or summit of a structure.

APODYTERIUM, (*αποδυμι, to put off*,) an apartment at the entrance of the ancient baths, wherein the bathers undressed.

APOLLODORUS, a most distinguished architect, born at Damascus, who flourished in the reigns of the emperors Trajan and Adrian, about the beginning of the second century. Under the former, he built the stone bridge over the Danube, which was esteemed one of the most considerable undertakings of that prince: he also raised several edifices round the forum Trajanum, at Rome, among which were the sculptured column of Trajan, still existing, and a triumphal arch.

Historians relate, that as Apollodorus was once conversing with Trajan about some architectural designs, Adrian interfered, and gave his opinion, which was treated by the artist with contempt: "Go," said he, "and paint gourds, (an amusement which he knew Adrian to be fond of,) for you are very ignorant of the subject on which we are conversing." This affront was not easily to be forgiven or forgotten; accordingly, when Adrian had succeeded to the empire, he sent to Apollodorus the plan of a temple he purposed erecting in honour of Venus, and desired to have his opinion, which, however, he did not intend to follow, being only desirous to show that he could do without his services. Apollodorus wrote his opinion freely, and pointed out such essential faults in the design, that the emperor could neither deny nor remedy them. But instead of acknowledging the merit and genius of the artist, Adrian threw himself into a violent passion, and banished him; and some time afterwards, under pretext of some supposed crimes, ordered him to be put to death.

APOMECOMETRY, (from *απο, from, μηκος, distance, μετρεω, to measure*,) the art of measuring things at a distance.

APOPHYGE, (*αποφυγειν*,) a concave quadrantal moulding, joining two vertical members of different horizontal projections, and forming an exterior angle with that which has the greatest projection, and a tangent with the other. The apophyge is used in the Ionic and Corinthian orders, for joining the bottom of the shaft to the base, as well as to connect the top of the shaft to the fillet under the astragal. The word is originally Greek, and signifies *flight;* and the French call it by a term which implies *escape*. English architects and builders also call it the *scape* or *spring* of the column. *See* COLUMN.

APOTHECA, (from *αποτιθημι, to lay aside*,) among the ancients, a store-room.

APOTHESIS. *See* APOPHYGE.

APPEARANCE, in perspective, the projection of a figure, body, &c., being the same as the representation of an original object. *See* PERSPECTIVE.

APPLICATE, in geometry, a right line drawn within a curve, and bisected by the diameter of the curve, otherwise called an *ordinate*.

APPLICATION, in mensuration, the art of applying one thing to another by approaching or bringing them together; thus any number of magnitudes of the same kind may be compared together by the successive application of a small magnitude of the same kind to each of them.

APPLICATION, in geometry, the act or supposition of placing one figure upon another, to find whether they be equal or unequal, which seems to be the primary mode by which the mind first acquires both the idea and proof of equality. In this way the first principles of geometry are demonstrated. Thus, if two triangles have two sides of the one equal to two sides of the other, and the angle included be also equal, then the two triangles are themselves equal in every respect:

conceive the one triangle to be so placed upon the other, with the two corresponding equal sides upon each other, the angles included by these sides being equal, the other sides will also coincide, and the two figures will agree in all respects. The same may be observed of other figures.

APRON, in plumbing, the same as FLASHING, which see.

APRON, a platform, or flooring of plank, raised at the entrance of a dock, against which the gates shut.

APRON-PIECE, or PITCHING-PIECE, a horizontal piece of timber in a wooden double-flighted stair, for supporting the carriage pieces or rough strings, and joistings in the half spaces or landings. The apron-pieces ought to be firmly wedged into the wall. *See* STAIRS.

APRON-LINING, the facing over the apron-piece.

APSIS, (from Greek *αψις, an arch,*) a term generally applied to any projecting portion of a building, having a semicircular or polygonal plan, and vaulted roof. In ecclesiastical structures, it signifies that part where the altar is situate, and which is reserved exclusively for the clergy. It differs from chancel in having the form above described. *See* CHANCEL.

APSIS GRADATA, a term peculiarly used for the bishop's seat or throne, in ancient churches, as it was raised on steps, above the ordinary stalls. It was also denominated *exedra*, and in later times, *tribune*.

APTERAL, a building without columns on its flanks or sides.

APYROI, (from *a, πυρ, fire,*) a name given by the ancients to altars, on which sacrifice was offered without fire. In this sense the word is in contradistinction to *empyroi*.

AQUEDUCT, or AQUÆDUCT, (from Latin *aqua*, water, and *duco*, to lead,) a construction upon or through uneven ground, for the purpose of forming a level canal for conducting water from one place to another. Aqueducts were formed either by erecting one or several rows of arcades across a valley, and making these arcades support one or more level canals, upon one or each of the ranges, or by piercing through mountains which would have interrupted the watercourse. They were built of stone or brick, and covered with a vaulted roof, or with flat stones, to shelter the water from the sun and rain. Some aqueducts were paved; but others conveyed the water through a natural channel of clay, to reservoirs or castella of lead or stone, whence it was brought to the houses by leaden pipes.

Aqueducts had also ponds disposed at certain distances, where the sediment of the water might be deposited. When the water was conveyed under ground, there were openings at about every 240 feet. Some of the Roman aqueducts brought water from the distance of sixty miles, through rocks and mountains, and over valleys, in places more than 109 feet high. The inclination of the aqueduct, according to Pliny, was one inch, and, according to Vitruvius, half a foot in the hundred. The proportions adopted by the moderns is nearly the same as that mentioned by Pliny. The principal aqueducts now remaining are—*Aquæ Virginia*, repaired by Pope Paul IV.; *Aquæ Felice*, constructed by Pope Sextus V.; the *Aquæ Paulina*, repaired by Pope Paul V. in the year 1611; and that built by Louis XIV. near Maintenon, to convey water from the river Bure to Versailles. This latter is perhaps the largest aqueduct in the world, it being 7,000 fathoms long, is elevated 2,560 fathoms, and contains 242 arcades.

ARABESQUE, or MORESQUE, an Eastern style of ornament, consisting of a fantastic mixture of foliage, flowers, fruits, &c., made use of both in painting and sculpture. Sometimes animal representations are introduced, but such are not strictly allowable.

ARABO-TEDESCO a style of architecture, exhibiting a mixture of the Moorish, or low Grecian, with the German Gothic. Of this style is the Baptistry at Pisa, erected by Dioti Salvi, in 1152. It is a circular building, with an arcade in the second order, composed of pillars with Corinthian capitals and plain round arches; between each arch rises a Gothic pinnacle, and above it is finished by sharp pediments, which are enriched with foliage terminating in a trefoil.

ARÆOPAGUS. *See* AREOPAGUS.

ARÆOSTYLE, or ARÆOSTYLOS. *See* INTERCOLUMNIATION and COLONNADE.

ARÆOSYSTYLE. *See* COLONNADE.

ARBOR, the principal part of a machine, which serves to sustain the rest. Also the axle or spindle on which a machine turns.

ARC (from the Latin *arcus*, a bow) in geometry, a part of any curve line which does not consist of contrary curvatures, for then two or more arcs would be formed, though in contrary directions.

ARC OF A CIRCLE, any part of the circumference less than the whole.

The line joining the extremities of an arc is called its chord.

Arcs are named after the angles which they subtend or are opposite to, and are measured by such angles and the radii of the circles to which they belong;—in other words, arc varies as angle $\times$ radius.

ARCS, *concentric*, are those that have a common centre.

ARCS, *equal*, such as subtend equal angles in equal circles.

ARCS, *similar*, such as subtend equal angles, whether in equal or unequal circles.

ARCADE, a range of apertures with arched heads, supported upon square pillars, or other columns. Arcades are sometimes employed to form porticos instead of colonnades; and though they are not so beautiful, they are stronger, more solid, and less expensive. In such buildings, the utmost care should be taken that the piers be sufficiently strong to resist the pressure of the arches, particularly the piers at the extremities, for they alone support the whole.

The lateral pressure upon the extreme piers in the range, will be equal to that on the piers of a single arch, and all the intermediate piers will be without such lateral pressure; for the lateral pressures of any two adjoining arches upon the intermediate piers are equal, and being opposite they destroy each other's effect: but the extreme pier having only one adjoining arch, must be sufficiently strong to withstand the horizontal thrust of that arch. The greater the weight or vertical pressure put upon the extreme piers, the more will these piers be able to counteract the thrust of the adjoining arch; consequently, if each extreme pier have to support a wall, the higher the wall, the less dimensions the pier requires. It is upon this principle, that the slender pillars, dividing the nave on either side from the aisle, in churches of the Saxon and pointed styles of architecture, are capable of withstanding the horizontal thrust of the groins; for if the insisting wall were taken away, the pillars of most of these buildings would not be able to withstand the thrust of the arches for one minute.

Arcades were employed in triumphal arches, theatres amphitheatres, and aqueducts of the Romans, and frequently in their temples: towards the decline of the empire, the intercolumns were formed into arcades; but what relates to their history will be found under the article ARCH.

Arcades may be used with propriety in the gates of cities, palaces, gardens, and parks: they are much employed in the piazzas or squares of Italian cities, and, in general, are of great use in affording both shade and shelter in hot and rainy climates; but they are nevertheless a great nuisance to the inhabitants, as they very much darken their apartments.

Lofty arcades may be employed, with great propriety, in the courts of palaces and noblemen's houses. There are various methods of decorating the piers of arcades, as with rustics, columns, pilasters, caryatides, persians, or terms surmounted with appropriate entablatures. Sometimes the piers are so broad as to admit of niches between columns or pilasters. The arch is either surrounded with rustic work, or with an archivolt, sometimes interrupted at the summit by a key-stone in the form of console, or mask, or some other appropriate ornament in sculpture. The archivolt rises sometimes from a plat-band, or impost, placed on the top of the piers, and at others from an entablature, supported by columns on each side of the arch. In some instances, the arches of arcades are supported entirely by single or coupled columns, without the entablature, as in the temple of Faunus, at Rome. This form is far from being agreeable to the eye, and it wants stability, as the columns would be incapable of resisting the lateral pressure of the arches, were they not tied together by a circular wall. In large arches, the key-stone should never be omitted, and should be carried to the soffit of the architrave, where it will be useful for supporting the middle of the entablature, which would otherwise have too great a bearing.

When columns are detached, as in the triumphal arches at Rome, it is necessary to break the entablature, and make its projection in the intercolumns the same as if pilasters had been used instead of columns, or so much as is just sufficient to relieve it from the naked appearance of the wall; this is unavoidable in all intercolumns of great width; but should be practised as little as possible, as it destroys the genuine use of the entablature. Arcades should never be much more, nor much less, than double their breadth: the breadth of the pier should seldom exceed two-thirds, nor be less than one-third of that of the arcade; and the angular pier should have an addition of a third or a half, as the nature of the design may require. The impost should not be more than one-seventh, nor less than a ninth; and the archivolt not more than one-eighth, nor less than a tenth of the breadth of the arch. The breadth of the bottom of the key-stone should be equal to that of the archivolt, and its length not less than one and a half of its bottom breadth, nor more than double. In porticos, the thickness of the piers depends on the width of the portico and the superincumbent building; but with respect to the beauty of the edifice, it should not be less than one-quarter, nor more than a third of the breadth of the arcade. When the arcades form blank recesses, the backs of which are pierced with doors, windows, or niches, the recesses should be at least so deep as to keep the most prominent part of the dressings entirely within their surface.

In the upper stories of the theatres and amphitheatres of the Romans, the arcades stood upon the podiums or inter-pedestals of the columns, perhaps as much for the purpose of proportioning the apertures, as to form a proper parapet for leaning over.

In Gothic Architecture—arcades, whether detached or engaged, are of very frequent occurrence; more especially in the Transition and early English styles. Engaged arcades are very common indeed, and may be found frequently running round the interior walls of a building, as at Westminster Abbey the Chapter-House, Canterbury, and in innumerable other instances; in the conventual buildings at Canterbury is a very fine specimen of a detached arcade. The engaged form came into very extensive use with the intersection of the semicircular arch, and was employed in almost every situation both on the interior and exterior of buildings, as well as in the decoration of their furniture, such as fonts, &c. The arcade indeed was a very prominent, if not the principal feature in all Gothic architecture, and is that which adds so greatly to the solemn grandeur of our noble cathedrals.

This term is also applied to any arched covered way, more particularly to the close passages recently introduced, such as the Burlington and Lowther arcades, which are used as promenades, as well as for purposes of trade.

ARC-BOUTANTS, (from the French, *arc*, an arch, and *bouter*, to abut.) *See* BUTTRESS.

ARCH. A structure composed of separate inelastic bodies, arranged in such a manner that their lower surface shall form the arc of a curve, being supported at its two extremities.

History. The invention of the arch has been assigned by different writers respectively to Babylonians, Egyptians, Greeks, Romans, and Etrurians.

The claim made for the Babylonians rests principally on a passage found in Strabo, wherein he states, that the Hanging-Gardens were formed by means of arches: a passage of Herodotus is also quoted, as favouring the supposition. This historian, speaking of the great gates in the city-wall, relates, that Nitocris was buried in a chamber above one of them, and it is urged by the supporters of this opinion, that so heavy a superstructure could not have been supported over an aperture of such dimensions by mere beams, or indeed by any other contrivance than that of the arch. On the other side it is argued, that Nitocris would have made use of the arch in the erection of her bridge, had the principles of its construction been understood, instead of the awkward application of horizontal timber beams; and with respect to the gateways, it is stated, that Herodotus, in this instance, speaks of jambs and lintels, and makes not the slightest mention of an arch. Besides, it is argued, if the arch was used to any extent, we should certainly find some vestiges of it in the ruins of that city, whereas the concurrent testimony of all travellers goes to prove that none such exist, while lintelling has been found in several instances, where the arch might have been applied with advantage.

In favour of the Egyptian title to this distinction, we are referred to specimens of arched work still to be found in the remains of Egyptian temples. The first specimen produced is from Abydos, where the roof is certainly of an arched form, but on inspection proves to be constructed of three horizontal stones; the centre one, which is the largest, overlapping the two side-ones. The under surface of these stones is cut out in such a manner as to form a semicircular arch. The other specimens adduced, are without doubt true arches, and if their antiquity be allowed, the question is at once set at rest. These arches are found at Thebes, and are formed of four courses of bricks arranged in a semicircle. If the fact of their antiquity, however, be admitted, it is difficult to understand why the arch should not have been more generally employed.

The same reasoning may be applied in the case of the Greeks, for, although it is said that true arches are found in their works, yet it seems probable that they were not in use previous to the second or third century before the Christian era, as, if so, we should naturally expect to find them employed in many cases where they would have proved

most useful. The general arrangement of their buildings would scarcely have been such as it is, if they had been acquainted with the principles of the art.

The first example of any arched construction to be found among the Romans, is that of the cloaca maxima, or public sewer, said to have been built by Tarquin. The identity of the existing remains with the original structure has been doubted, but in fact this is of no great importance, as there is no scarcity of examples of this kind, although of somewhat later date than the reign of Tarquin. There are some who assign the merit of the introduction of the arch among the Romans to the Etrusci, and who are not entirely without reasons for this assumption. They say that Tarquin brought this knowledge with him from Etruria, his native country, and that Etrurians were employed by him in the construction of the sewer; others, however, refer the actual construction to Greeks. It is possible indeed that the Etrurians may have introduced this form of building, as it is well known that that people had arrived at some excellence in the arts at an early period, and also were in close communication with the Romans; be this, however, as it may, there can be no doubt that we are principally indebted to the latter people for the full development of the power and utility of the arch; whoever it may have been who first became acquainted with the principles, whether Egyptians, Greeks, Romans, or Etrurians, there never was any doubt as to the people who carried its knowledge into execution. As far as the Greeks or their predecessors are concerned, we might have remained in utter ignorance as to the utility of this style of building. It is to the Romans we owe our practical knowledge on the subject; they it was who made a worthy application of their knowledge, and put their theories into extensive execution; and although they employed this form to a greater extent than perhaps good taste might sanction; yet this we judge to be the natural procedure of any people upon first becoming acquainted with a principle of so peculiar a character and such unlimited usefulness.

Although the Romans employed arches in the construction of their edifices, to a very great extent, yet they always confined them to one form, namely the semicircular. It is to the architects of the middle ages we are indebted for the great variety of figure employed in this kind of construction; among others we may especially notice the pointed arch,—but for further information on this subject, we beg to refer the reader to that particular style of architecture.

Of the forms, &c. of arches. Arches are named according to the curve assumed by them, as circular, elliptical, cycloidal, parabolical, hyperbolical, catenarian, &c.: circular arches are again subdivided according to the quantity of the circumference described by them, such as semicircular, segmental or surbased, containing less than the semicircumference, surmounted, horse-shoe or Moorish, containing more than the semicircumference. Arches are also denominated according to the method adopted in describing the curve, as two, three, or four-centred arches; also by the nature of the angle formed at the apex, thus, pointed arches are distinguished by the appellation of lancet, equilateral, and depressed. Further, there are arches of equilibration and of discharge; askew and reversed arches.

The separate masses or stones, of which the arch is composed, are called *voussoirs* or *arch stones*, the central or uppermost of which is called the key-stone, the lowermost, or those nearest the supports, *springers*. The highest point in an arch is termed the *vertex*, or *crown*, the lowest line the *springing line*, and the spaces between the crown and springing line on either side, the *haunches*, or *flanks*. The under or concave surface is denominated the *intrados*, the upper or convex the *extrados*. The supports of an arch are called *piers*, *abutments*, *springing walls* or *reins*. Piers are distinguished from abutments, the former term being applied to a support to resist a vertical pressure, the latter an horizontal thrust. The upper parts of the supports on which the arch rests, or from which it is said to *spring*, are named *imposts*. The *span* of an arch is the width between the points, where the intrados meets the imposts on either side, which in the case of circular arches coincides with the chord of the arc: the *rise* is the height of the highest point in the intrados above the *springing* or *spanning-line*.

Arches which have the curves of both intrados and extrados concentric or parallel, are said to be *extradossed;* and such as rise from supports at unequal heights, are called *rampant arches*. There are other kinds of arches, but these are more applicable to VAULTING, under which head they will be treated of.

In order to avoid farther extending this article, we must refer the reader for the THEORY of the ARCH, to STONE BRIDGE.

ARCH, TRIUMPHAL; an edifice erected by the Romans in various situations, but more especially at the entrances of their cities, in honour of victorious generals, and in later times of the emperors. These structures were originally built of brick, but afterwards of stone, or marble; their form was that of a parallelopipedon, having one, and often three, arched apertures in the longer side, decorated with columns, sculpture, and other embellishments; the whole being surmounted with a heavy attic. When three arches were employed, they were situate so as to have one large one in the centre with a smaller one on each side of it.

Under the emperors, triumphal arches became very numerous, and were made of costly materials richly ornamented. The oldest of such structures remaining in Rome is that of Titus, enriched with sculptures representing the triumph of that emperor. Two other arches erected in honour of Trajan are still in existence, the one at Ancona, the other at Benevento; the former is of white marble of chaste ornamentation, consisting in part of bronze statues; the latter has several fine relievos, and is in a state of good preservation. The above are single-arched; several, however, were constructed of three arches, amongst the most remarkable of which are those of Constantine and Septimius Severus; that of Constantine has been cleared of the soil which had accumulated to some height round its base, and is perhaps the most beautiful and complete of any at Rome, but manifests some discrepancies of parts, as it was built partially of old materials from an earlier monument of Trajan; that of Severus is a noble structure, but is much more dilapidated; it is sixty-one feet in height, seventy-one in length, and twenty-two in depth, the central archway is twenty-two feet wide, and thirty-six high, the side ones ten feet wide, and twenty-two feet high.

But few structures of this kind have been erected by the moderns; amongst them, however, we may notice one triple arch of Bonaparte on the Place du Carrousel, and a much finer one at Milan.

ARCHEION, the treasury, and most secret and retired place in Grecian temples, where not only the richest treasures appertaining to the deities were deposited, but also other valuable articles, which they were desirous of keeping secure. The practice of the Romans was very similar to that of the Greeks, but they confined the deposition of their public treasure to the temple of Saturn.

ARCHITECT, (Greek αρχος τεκτων, *the chief fabricator.*) In considering the correct application of this word, we shall

not confine ourselves to any one period of time, as the word has been variously applied under different circumstances. We find the word ἀρχιτέκτων employed by Herodotus, and also by Homer, in their respective works, who seem to have given to it a very extensive signification. In one and the same passage, (iii. 60,) Herodotus uses the term in two different senses, for he speaks of the "architect" of a tunnel for supplying water, as well as of the "architect" of the great temple of Samos. Homer uses the same term to signify a carpenter, a house-builder, and also a ship-builder. It seems probable, then, that in these early ages, the word "architect" was not restricted to any one signification, but was applied as circumstances required. In succeeding ages, however, when the more perfect civilization of mankind required structures not only more numerous and more elegant, but also in greater variety, and suited to multifarious uses, it was found inconvenient, if not utterly impracticable, for any single individual to qualify himself to superintend the construction of so great a variety of buildings. Thus resulted a division of labour: the duties of the "architect" were alleviated by allotting to several the task originally undertaken by one. Thus arose the distinct duties of architect and engineer, which are again subject to several subdivisions, distinct departments of one grand and comprehensive whole.

ARCHITECTOGRAPHIA, the description of ancient buildings, as temples, theatres, amphitheatres, triumphal arches, baths, pyramids, tombs, mausoleums, aqueducts, &c.

ARCHITECTURE, the art of building. Did we apply to this word the signification derivable from the original Greek, we should have before us a very extensive field for investigation. Custom, however, has limited the application of the term to the science of erecting artificial structures.

The origin of this department of science is involved in impenetrable obscurity. It is reasonable to expect that man, a being of acute feelings, should soon have sought out some method of protecting himself against the inconveniences to which his physical conformation rendered him obnoxious. Exposed to the vicissitudes of the weather and the variations of temperature, he must, at a very early period, have discovered some means of shelter and security; the method, however, which he adopted for effecting this object is left entirely to conjecture. Various speculative opinions have been hazarded on the subject, remarkable for the most part not more for the inventive imaginations of their authors, than for the crudeness and absurdity of the speculations themselves. Vitruvius, the first writer on the subject, has given a very elaborate, if not very correct account of the contrivances of our primeval ancestors in the way of house-building; this account, strange to say, has been transmitted as an authority from time to time almost down to our own age, gathering in its progress additional strength from the names of those who have given credence to its manifold absurdities.

In considering the subject, we must not forget that mankind originally inhabited a warm climate, where the inclemency of the weather was comparatively but little felt, and where consequently there was no need of such defences as in a colder region. The chief inconvenience arose probably from the extreme heat, a natural retreat from which was found in the shelter afforded by the luxuriant foliage of the trees. We might reasonably suppose that, as there was no necessity for a very substantial edifice, tents formed of the skins of beasts offered in sacrifice, or of other convenient substance, would have formed the primitive dwellings of mankind; this, however, there is some reason to suppose, was not the case, as we read that Jabal was the father of such as dwelt in tents, whereas Cain had built a city sometime before Jabal's birth. What this city was, we have no means of judging; of its materials and its form we are alike ignorant. The next mention made of a city in the sacred writings is that of Babylon, which was built by Nimrod; here it was that the famous tower of Babel was commenced, in the building of which, it is stated, burnt bricks and slime (bitumen) were made use of. The same Nimrod is related to have built Nineveh and three other cities. Whether the above were the first cities that were built after the flood is left doubtful, for we find no mention in the sacred history of any Egyptian cities, yet doubtless such must have existed at a very early period; we cannot, therefore, say for certain whether the sons of Cush or Mizraim took the precedence in such works; nor can we tell whether the buildings seen by Herodotus and other pagan historians were in any part the same as those whose erection is mentioned by Moses. These, as well as all other subjects connected with the early ages of mankind, must ever remain matters of mere conjecture; yet with respect to the latter question, it does appear somewhat worthy of attention, that Herodotus relates having visited, situate in the midst of Babylon, a tower of vast dimensions and unusual height; the coincidence of the two accounts is, to say the least, remarkable. If we allow the towers spoken of by the two historians to be identical, and also that the separation of mankind did not take place, at least to any extent, before the confusion of languages, we shall have no difficulty in accounting for the remarkable affinity of the Persian, Hindoo, and Egyptian architecture, especially with reference to the pyramidal form of their structures: we shall also be enabled to form some notion of the progress of mankind in this art, as well as of the nature and method of building at the period.

We have hitherto been considering the first rise and progress of architecture in the earliest ages of the world; we must bear in mind, however, that some people in later ages have, by some means or other, lost all traces of the civilization of their ancestors. This fact may appear strange, but it is not our part to account for it in this place; the fact is before us, startling perhaps, but undeniable notwithstanding. We intend here briefly to consider, how those people, after having lost all their previous knowledge of architectural science, set about to regain it. And here we might introduce the theory of Vitruvius, but not, as he does, in the shape of a general fixed rule; for although it may be true, even in the majority of cases, that the first rude attempts in the erection of dwellings have been, as he states, of a conical form, yet this was by no means universally the case. The fact is, the method of building so much depended upon the character of the people, the nature of the locality inhabited by them, as well as that of its productions, upon the materials and resources for building, and lastly, upon the examples which nature more prominently set before them; that it is utterly impossible to lay down any rule as that by which mankind have been universally governed in the erection of their first structures.

Although Architecture had its rise doubtless in the construction of buildings for the purposes of shelter and defence, yet it is no less certain that it is indebted for its rapid advancement, and its ultimate perfection, to the religious feelings of mankind. It is in the temples we look for beauty of design, for appropriateness of embellishment, for grandeur, ideality, and magnificence. Had it not been for religion, architecture would never have risen to that eminence which it so early attained in the sacred edifices of the ancients; and which have attracted such universal admiration. It is

to temples, then, we must look for the progress of a people in this great art; by them must we compare nations as to their advancement in skill, taste, and science, as well as in the general progress of civilization.

Having thus far considered the origin of Architecture as a science, we shall now give a very concise sketch of its progress in different countries.

Our very first steps in entering upon the history of Architecture are greatly impeded for want of trustworthy information on the subject. We are left in the dark as to what style may justly claim precedence in point of time. Following the account of the creation and civilization of mankind, as given by Moses, we should naturally enough look towards the East for the first origin of this, as of all other arts, and this supposition is confirmed as well by the concurrent testimony of history, as by the investigation of the remains of Eastern edifices. But although we may, without hesitation, yield the priority to the ancient Eastern edifices as a whole, we still meet with difficulties in assigning its proper position to each separate style. We should prefer to place the Babylonish or Persian architecture first on the list, as well for the reason previously assigned, as that, as far as we are enabled to judge from the specimens that remain to us in the ruins of Babylon, the buildings of this style appear to be of ruder construction than those either of India or Egypt. For this latter cause, we should give to Egypt the next place, as we find the sculptures of India of more rounded form, and more elaborate workmanship than the Egyptian.

In endeavouring to give to each style its relative chronological position, we do not mean to deny that they were equally indebted to each other for various improvements at different periods. We would especially instance the case of Persepolis, the principal specimen of Persian architecture remaining to us: here we find truly a great advance upon the architecture of Babylon, and we can have no doubt respecting the introduction of some peculiarities of the Egyptian style. Whatever doubts, however, there may remain concerning the relations of the above styles, separately, in respect of age, there can be none as to their general resemblance and affinity, or as to their position, taken as a whole, in the chronology of Architecture.

Next in the order of age comes Grecian Architecture. Here again Vitruvius has given us some very fanciful suggestions respecting the prototype of the entire edifice, as well as the origin of its varied details; nothing, however, can be more absurd than his notions respecting the latter; and as to the former, he gives the Greeks credit for inventive genius, which certainly cannot lawfully be claimed for them. We may, with equally the same justice, yield to them their boasted title of *αυτοχθενες*, as their claims to originality in their style of building. Obscure as are the traditions respecting the colonization of Greece, we have ample evidence to show that it was indebted to Egypt, Phœnicia, and other parts of the East, for the majority of its inhabitants; add to this the similarity existing between the earlier styles of Grecian architecture, and those of Egypt and Persepolis, and there can, we think, remain no hesitation in assigning to the latter the origin of Grecian art. While, however, we refuse the claims of Greece to originality, we cannot forget how much we are indebted to her for the introduction of so many and valuable improvements. In her hands this department of art arrived at its greatest excellence, insomuch as to form a new era which for purity and chaste grandeur has never been surpassed.

The great distinction between the last mentioned and the Roman style is in the employment of the arch. The use of the arch gave the Romans great advantage over all previous nations, and permitted of great variety in the construction of their buildings. This people aimed rather at utility than ornament; and although many of their buildings are well worthy of admiration on account of their appropriateness to the purposes for which they were intended, and even of some degree of beauty, yet they may not be compared with the purity and grandeur of Grecian taste. The Greeks were lovers of art for its own sake, the Romans for the sake of the benefits it afforded them. We must not, however, consider the Romans as devoid of taste or original conception, for they may claim the Corinthian order almost entirely as their own, and this says not a little for their appreciation of the beautiful. They had this advantage also over the Greeks, that whereas the latter were confined to one plan, the parallelogrammic, which gave their structures a monotonous appearance, they, on the contrary, could vary the form in any way they deemed suitable; and this introduced the practice of grouping, or composition, as it is called. The introduction of another practice we owe to the Romans, namely, that of internal decoration. Thus, while the Greeks may claim the palm for purity of taste, the Romans take precedence in utility and variety of construction.

Having thus considered the history of our subject from its earliest commencement to the perfect development of the great principles of construction, we deem it advisable to postpone the consideration of the later styles to their respective heads. We have now arrived at the grand model of all future eras, and to which all modern styles owe their origin. The Romans, owing to their wide-spread dominion, have introduced their knowledge of the arts throughout almost the entire world, and so their architecture has been the grand prototype of all succeeding ages. For although the variation of different styles from each other, and also from their common pattern, be considerable, yet there can be no doubt as to the source from whence they all had their origin. It is true that, at first sight, the elaborate edifices of the style known under the name of Perpendicular, seem to have but little affinity to the heavy Norman structure; and yet when the intermediate links are added to the chain by which they are connected, few persons will be found to question their immediate relation; and certainly the step between the Norman and late Roman requires but little explanation. Considering, therefore, the Roman as the foundation upon which medieval, as well as modern architecture was erected, we leave each style to be considered under its separate title.

It is our intention to enter into a more minute investigation of this subject under the following heads:—BABYLONIAN ARCHITECTURE, BYZANTINE, CELTIC, CHINESE, EGYPTIAN, ENGLISH, ETRUSCAN, GOTHIC, GREEK, HINDOO, ITALIAN, MEXICAN, MOORISH, NORMAN, PELASGIAN, PERSIAN, POINTED, and ROMAN.

ARCHITRAVE, (from *αρχος*, *chief*, and *trabs*, *a beam*,) that division of the entablature which rests upon the columns, and which may perhaps represent the linteling beam placed over the columns, and over the intercolumns, for supporting the cross beams, in the roof of the primitive wooden structure.

In the remains of ancient Grecian structures, the architrave is of very great height, being nearly equal to the superior diameter of the column, and in some instances even more, as in the Doric temples of Theseus at Athens, Corinth, near the ancient city of that name, Pæstum in Italy, and in the Ionic temple on the river Ilissus at Athens; but there are few or no instances where it is so high as to be equal to the inferior diameter. Examples in which the lowest architraves are to be found are the portico of Philip, king

of Macedon, and the Doric portico at Athens; the altitude of the former being only thirty-eight minutes, and that of the latter forty-five minutes, or two-thirds of the bottom diameter. In the remains of Roman buildings, the architraves are low, being in most cases between two-thirds and three-fourths of a diameter. The lowest architrave in these remains is that of the theatre of Marcellus at Rome, which is only half a diameter. This proportion has been generally followed in the Doric order by the modern restorers of ancient architecture. What relates particularly to the forms and parts of the architrave of each particular order will be seen under the heads of TUSCAN, DORIC, IONIC, CORINTHIAN, and ROMAN ORDERS.

The soffits of the architraves of Grecian buildings are always found to exceed the upper diameter of the columns; but in the Roman they are equal.

In the Saxon and early Norman styles of architecture, arches rise from the capitals of the pillars, instead of being linteled by the architrave as in the Egyptian, Grecian, and Roman buildings: this is one of the most striking differences between ancient architecture and the styles afterwards practised in the middle ages.

ARCHITRAVE OF A DOOR, a collection of members surrounding the aperture, of a section similar to the architraves of the Ionic, Corinthian, and Roman orders. The head or lintel is called the *traverse*, and the sides the *jambs*. Vitruvius calls the jambs *antepagmenta*, and the head or traverse *supercilium*. In the remains of the edifices at Balbec and Palmyra, and in the palace of Diocletian at Spalatro, the architrave jambs are often flanked with consoles, which gives an apparent support to the cornice, and the cornice frequently rests upon the traverse, without the intervention of the frieze; but the flank pilasters under the consoles are scarcely to be met with among ancient ruins, though practised by the modern Italians, and represented in their works. This is however an improvement, as it diminishes the apparent weight of the top, by spreading out the lower part. The proportion of the architrave to the aperture, in ancient edifices, varies greatly: the usual proportions given by the moderns is from one-seventh, to one-sixth part of the opening. When the architrave jambs are flanked with pilasters and consoles, the breadth may be one-seventh of that of the aperture, and the breadth of the pilasters two-thirds of that of the architrave; but when it is unaccompanied with these ornaments, it ought not to be less than a sixth part of the breadth of the aperture.

In the ruins of Roman and Grecian buildings the architrave rests upon the floor, and has no flanking consoles; but in the ruins of Balbec they are supported by plinths.

When there is too much surface of naked wall on each side of the architrave jambs, the sides of the architrave may be flanked with pilasters and consoles, in order to reduce the naked, and proportion it to the dressings of the front. The dressing of an aperture may be heightened by adding a cornice, or a cornice and frieze, as the space above will admit; and if the space above requires further diminution, the altitude of the dressing may be still further increased, by surmounting the cornice with a pediment. When the material of the architrave is stone, the jambs are either built in heights corresponding to the courses of the naked of the wall, or if stones can be procured, each jamb is made of one entire piece, or sometimes in two or three, according to the difficulty of raising them from the quarry.

When they are coursed with the work, every alternate stone should be a bond-stone, and, if the jambs are in one height, or not coursed, every alternate stone in the altitude of the naked, adjoining each architrave jamb, should be a bond-stone: the fewer pieces the architrave jamb consists of, the more beautiful will the work appear, therefore one is preferable to several.

In the arched apertures of ancient buildings, the jambs are seldom or never moulded as an architrave, but the arch is frequently ornamented with members of an architrave section; these members are called the archivolt, which always rests upon imposts. The imposts project in most cases from the naked of the wall, and in a few cases form the capital of pilasters upon the jambs.

ARCHITRAVE, in joinery, is one constructed of wood. Architraves may be wrought out of a solid piece of wood; this, however, would be attended with a waste of both stuff and time. The best method is to glue it up in two or more longitudinal pieces, as may be judged proper from the combination of its parts. For a full description of this method, see JOINERY.

ARCHITRAVE CORNICE, is an entablature which consists of an architrave crowned with a cornice, without the intervention of the frieze. There are few ancient examples where an architrave cornice is supported by columns or pilasters: the only ones which we can recollect are, that on the inside of the portico of the Pantheon, and the entablature of the third order of the Colosseum at Rome (if it may be so called) and that supported by the caryatides of the temple of Pandrosus at Athens: the imposts of the arch of Septimius Severus are also formed like an architrave cornice. The remains of antiquity exhibit many instances where the dressings of rectangular apertures are finished with architrave cornices, as in the temples of Erechtheus at Athens, Vesta at Rome, and in other ruins exhibited in Adam's *Spalatra*, and in Wood's *Balbec and Palmyra*.

ARCHITRAVE JAMBS. *See* ARCHITRAVE OF A DOOR.

ARCHIVAULT. *See* ARCHIVOLT.

ARCHIVE, an apartment wherein the records or charters of a state or community are preserved, in order to be consulted occasionally.

The word comes from the Greek αρχαιον, which signifies that part of their temples in which the public treasury was deposited. Colleges and monasteries had all their archives; but that of the Romans was restricted to the temple of Saturn in particular.

ARCHIVOLT, a collection of members on the face of an arch, adjacent to, and concentric with the intrados, supported upon the imposts. The word is derived from the French *archivolte*, which signifies the same thing as *arcus volutus*.

The archivolts in Roman and Grecian edifices are formed upon the face of the arch with their section perpendicular to the curve of the intrados and the wall, and similar in figure to that wrought on the face of an architrave; the intrados being, in most cases, the surface of a cylinder, and, in some few cases, that of a cone. In the latter ages of the Roman empire, arches with archivolts were substituted instead of the horizontal entablature, by supporting the arches upon the capitals of columns as imposts. This innovation gave birth to that style of building most commonly known by the name of Gothic, and forms one of the most characteristic features of this style of building. The archivolts of Saxon edifices were at first very similar to those of the Romans, but in process of time, the pillars became clustered with small columns, and each shaft of the clustered pillar had its separate capital; therefore, in order to make the bottom extremities of the arch bear equally on the tops of the pillars, it became necessary to form the archivolt in deep recession from the soffit, rather in a conical than a cylindrical surface. The archivolt was separated into several

similar divisions, each one consisting of a collection of mouldings, with deep sinkings between.

ARCS DOUBLEUX, the soffits of arches.

AREA, in architecture, is the surface of the ground of a court, or the bottom of the part of an excavation sunk below the general surface of the ground, before the basement story of a building, and level with its floor.

AREA, in geometry, is the quantity of surface on a body, or the superficial extent of any figure.

ARENA, the plain space in the middle of the Roman amphitheatre, where the gladiators fought: the same term was also used by the Romans to denote the amphitheatre itself. This term is further applied to the body of a temple, including the whole space between the antæ and extreme wall.

ARENATUM, a word used by Vitruvius to signify a kind of plaster: mortar made up of lime and sand.

AREOPAGUS, a place near Athens, where the Athenians held their court of justice.

ARONADE, *Embattled*, a conjunction of several lines, forming indentations like the boundary of an embattled wall, except that the middle of every raised part is terminated by the convex arch of a circle, which arch does not extend to the length of that part.

ARRIS, the intersection, or line, on which two surfaces of a body forming an exterior angle meet each other. This term is much used by all workmen concerned in building, as the arris of a stone, of a piece of wood, or of any other material. Though the edge of a body conveys the same meaning in general language as arris, yet, in building, the word *edge* is restrained to those two surfaces of a rectangular parallelopipedal body, on which the length and thickness may be measured, as in boards, planks, doors, shutters, and other framed joinery.

ARRIS FILLET, a slight piece of timber of a triangular section, used in raising the slates against chimney shafts, or against a wall that cuts obliquely across the roof, and in forming gutters at the upper ends and sides of those kinds of skylights that have their plane coinciding with that of the roof.

When the arris fillet is used in raising the slates at the eaves of a building, it is then called the eaves-board, eaves-lath, or eaves-catch.

ARRIS GUTTER. *See* GUTTERING.

ARSENAL, a public store-house for depositing arms or warlike ammunition.

ASAROTUM, a kind of painted pavement, used by the Romans before the invention of Mosaic work. The most celebrated was that painted by Sesus at Pergamus, which exhibited the appearance of crumbs, as if the floor had not been swept after dinner.

ASHLAR, among builders, signifies common or free-stones, as they come from the quarry, of various sizes.

ASHLAR, the facing of squared stones on the front of a building. When the work is smoothed or rubbed, so as to take out the marks of the tools by which the stones were cut, it is called *plane ashlar*. *Tooled ashlar* is understood to be that, the surface of which is wrought in a regular manner like parallel flutes, and placed perpendicularly in the building; but when the surfaces of the stones are cut with a broad tool, without care or regularity, the work is said to be *random-tooled:* when wrought with a narrow tool, it is said to be *chiselled*, or *boasted:* and when the surfaces of the stones are cut with very narrow tools, the ashlar is said to be *pointed*. When the stones project from the joints, the ashlar is said to be *rusticated:* in this kind, the faces may either have a smooth or broken surface. Neither pointed, chiselled, nor random-tooled ashlar are employed in good work: in some parts of the country, herring-bone ashlar, and herring-bone random-tooled ashlar are used.

ASHLARING, is the act of setting an ashlar facing.

ASHLERING, in carpentry, is the fixing of short upright quarterings between the rafters and the floor in garrets, in order to make more convenient rooms by cutting off the acute angles at the bottom. The triangular spaces on the sides are either left unoccupied, or formed into cupboards or closets.

ASIMINTHOS, a large vessel used by the Greeks for bathing in.

ASPHALTUM, a kind of bituminous substance, found sometimes in a solid, sometimes in a soft or liquid state, in various parts of the world. A species of it discovered in Neufchatel, has been used with great success, as a cement for walls and pavements; it is very durable in air, and impenetrable by water. Of late years, various combinations of Asphaltum with other materials have been employed under the name of Asphalte, or Asphaltic Cement, for covering roofs, floors, &c., and for other useful purposes. The best of these "Asphaltes" is that known as "*Claridge's Asphalte of Seyssel*," which has a deserved reputation as an excellent pavement, and valuable material for the different purposes above named.

ASSEMBLAGE, the joining or uniting of several things together, or the things themselves so united. Carpenters and joiners have various kinds of assemblages, as by mortise and tenon, dove-tailing, &c.

ASSEMBLAGE OF THE ORDERS, the placing of the columns upon one another in the several ranges, so that their axis shall be in the same straight line.

ASSERS, in ancient carpentry, were the laths which supported the tiles of the roof: from the projecting ends of these the denticulated cornice is supposed to have originated: they were not disposed horizontally, but according to the inclination of the roof; and hence Vitruvius forbids the use of dentils in pediments.

ASSERS were also the ribs of brackets of an arched ceiling.

ASTRAGAL, (from ἀςραγαλος, the *heel-bone*,) a moulding of a semicircular section, projecting from a vertical diameter. It is remarkable that Vitruvius does not mention any astragal between the shaft and the hypotrachelion of the Doric and Tuscan columns, as is to be found in the Doric of the theatre of Marcellus, at Rome; so that it is probable, the hypotrachelion might be formed without any mouldings whatever, by making it recede in a small degree within the shaft, or by fluting it, as in the column of Trajan. This doctrine is also very conformable to all the Grecian examples of the Doric order; for the hypotrachelion is separated from the shaft by one, two, or three annular channels, without any projecting moulding, and the flutes are continued upwards through the hypotrachelion, to meet the under side of the annulets. In the Ionic order of the temple of Erechtheus, at Athens, the hypotrachelion is however separated from the shaft by an astragal; and in the temple of Minerva Polias, at the same place, they are separated by a plain fillet.

In all the other numerous Grecian examples of this order there is no hypotrachelion: the astragal is placed immediately below the echinus. The same is to be found in the few remaining Roman examples of this order. In the Corinthian and Composite orders, the astragal is never omitted between the under row of leaves and the shaft, except in the Corinthian of the monument of Lysicrates, at Athens, which is one of the oldest examples of this order; where, instead of the astragal, there is an annular groove, from which, and

from the beauty and delicacy of this example, it seems probable that the astragal might be originally formed of a metal ring.

The astragal is a moulding of very frequent application, not only at the upper ends of the shafts of columns, but also in their bases and entablatures. It is the simplest of all mouldings, and the only one which can stand alone by itself, and project from a plane surface without the aid of a fillet or straight part.

The Greeks and Romans frequently cut their astragals into beads, formed alternately of oblate and prolate spheroids, or, instead of prolate spheroids, figures consisting of double cones, with cylindrical parts between, are introduced: this practice is followed by the moderns with various innovations.

In the Egyptian architecture, we meet frequently with clusters of astragals, circumscribing the shafts of the columns; in various places dividing them into several compartments, of which some of them are frequently receded vertically with astragals. The capitals often join upon the tops of the shafts, without any horizontal moulding between them.

The astragal and torus are exactly similar figures: the only distinction is, that when they are compared with the other, in the same piece of work, the torus is large, and the astragal small, perhaps not exceeding one-third part of the diameter of the torus; but in most cases any proportion less, so that it may be sufficiently distinct.

ASULÆ, marble chips.

ASYMPTOTE, a straight line, which continually approaches to a curve without meeting it.

ATHENEUM, or ATHENÆUM, the name applied in ancient times to public buildings erected for rehearsals and lectures. In modern times, the title of Athenæum has been frequently given to establishments connected with literature and art, public reading-rooms, &c.; a celebrated club-house in London is called the Athenæum.

ATLANTES, ATLANTIDES, or ATLAS, the name given by the Greeks to the figures or statues of men used to support entablatures with mutules instead of pilasters or columns. They were also called ZELAMONES and PERSIANS.

In the architecture of the modern Italians, the Atlantes are often found supporting the entablature over an entrance to a palace or garden. At Milan there is a colossal example of the former; and the rustic gate to the Farnese Gardens at Rome is a specimen of the latter.

ATRIUM, a court or hall in the interior of the Roman noblemen's houses, of an oblong plan. Three sides of the atrium were supported on columns, the materials of which, in later times, were marble. The side opposite to the gate was called *tablinum*, and the other two sides *alæ*. The tablinum was filled with books, and the records of what any one had done in his magistracy. It was in the atrium where the nuptial couch was erected, where anciently the family used to sup, where the mistress and maid-servants wrought at spinning and weaving, and where the clients used to wait on their patrons. The atrium was adorned with pictures, with statues of their ancestors, and with plate; and was usually the most splendid and important part of a Roman house.

In later times, the atrium seems to have been divided into different parts, separated from one another by hangings, into which persons were admitted, according to their different degrees of favour. The atrium was frequently in ancient times confounded with *vestibulum*, which was only a recess on the exterior side of the building, and what is now called by the Italians *loggia*.

Even Vitruvius, in chap. iii., book vi., confounds it with *cavædium*, which was an enclosure still further within the interior. This author assigns three different proportions to the length and breadth of the atrium: the first is 5 to 3, the second 3 to 2, and the third is the ratio which the diagonal of a square has to its side. Their height to the under side of the ceiling is equal to their length, wanting a fourth part. The difference between the atrium of a city and country residence was this, that in the former it was placed near the entrance, and in the latter, the peristylium was placed between the atrium and the gate.

The Greeks had no atrium in their houses. In some temples an atrium was to be found.

ATRIUM, in ecclesiastical antiquity, a large open court before a church, making part of what was called the *narthex*, or *ante-temple;* it was surrounded with a cloister or portico. In this apartment the penitents stood to beg the prayers of the faithful, as they went into the church; and here those remained who were not suffered to go further into the church.

ATTIC, is a part of a building standing on the cornice, similar in form to that of a pedestal, and is either broken or continued. It is so named from its being supposed to have been first used in Attica. The use of an attic is to conceal the roof, and give greater dignity to the design. The Romans employed attics in their edifices, as may be seen in the remains of the triumphal arches, and in the forum of Nerva. In the arch of Constantine, pedestals are raised over the columns as high as the base of the attic, and these pedestals are again surmounted with insulated statues. In the ruins of Athens there are no attics to be found; except one over a Corinthian colonnade at Thessalonica, with breaks forming dwarf pilasters over the columns, and with statues placed in front of the pilasters, as in the arch of Constantine. The attic carried round the two courts of the great temple of Balbec, is also broken into dwarf pilasters over the columns and pilasters of the order; and the dwarf pilasters have blocking courses over them, on which statues are supposed to have been placed. Attics are very disproportional in the ruins of these ancient edifices, some of them being nearly one half of the height of the order. The moderns make their height equal to that of the entablature: as to the proportion of the height of the members, it may be the same as that for pedestals.

The pilasters employed in attics are sometimes plain, and at other times panelled; they have no diminution, nor any regular base and capital. Attics are much used by the moderns, particularly by Italian architects; and when applied to modern houses, they have frequently windows in the podium or dado.

Amongst the best examples of the use of the attic in modern public buildings, may be adduced Somerset House, in the view towards the street.

ATTIC BASE, is that which consists of an upper and lower torus, a scotia, and fillets between them. It is described by Vitruvius as follows:—"The bases are fixed in their places, and so proportioned, that, including their plinth, they have in height half the thickness of the column; and in projection what the Greeks call εκφοραν, *ekphoran*, a quarter: so that the breadth and length will be once and a half the thickness of the column. Their height, if they are to be attic, must be so divided, that the upper part is one-third of the thickness of the column, and the remainder is left for the plinth. The plinth being excluded, the remaining part is divided into four equal parts, and the upper torus has one-fourth: the remaining three are equally halved: one-half makes the lower torus, and the other the scotia, which the Greeks call τροχιλον *trochilon*, with its squares."

In many examples, both Grecian and Roman, the fillet over the trochilus projects as far as the most prominent part of the upper torus, and leaves a deep recess between the upper surface of the fillet and lower side of the torus. This base seems to be as much a favourite of the moderns as it was of the ancients.

Attic Door. *See* Door.

Attic Order, a term improperly used to denote the pilasters which are frequently employed in the decoration of an attic.

Attic Story, a term frequently applied to an upper story of a house.

ATTITUDE, in painting and sculpture, the posture or action in which a figure or statue is placed.

ATTRIBUTES, in painting and sculpture, are symbols given to figures.

AUDITORY, in ancient churches, the *nave*, where the people stood to be instructed in the gospel.

AUGER, a carpenter's and joiner's tool, for boring large holes with, and formed of a wooden handle, and iron spindle, terminated at the bottom with steel. The modern augers are pointed and sharpened like a centre-bit, the extremity of one of the edges being made to cut the wood clean at the circumference, and the other to cut and take away the core, the whole length of the radius.

AULA, a court or hall in the ancient Roman houses.

AXE, a tool with a long wooden handle, and a cutting edge in a plane passing longitudinally through the handle. Its use is for hewing timber, by cutting it vertically: the adze being employed in forming horizontal surfaces. The axe differs from the hatchet in being much larger, and by its being used with both hands; while the hatchet is used with one hand only. Axes are also used by stone-cutters and bricklayers, the particular forms of which depend upon the quality of the materials. *See* Tools.

AXIS, of a rotative figure, is the straight line passing through the centres of the circular sections at right angles to them. In a sphere, any right line passing through its centre may be the axis.

B.

BABEL, a city and tower built by Noah's posterity in the plain of Shinar. Its precise situation is not ascertained. It was however within the province of Shinar, and, probably, the ancient Babylon was but an enlargement of it. Its situation is supposed to have been on the north-west of Bagdad, on an extensive plain, between the Euphrates and the Tigris; as an extensive, insulated, shapeless heap of ruins is there to be seen, called the tower of Nimrod.

In sacred Scripture we are informed, that the materials of which this tower was constructed were burnt brick, and slime for mortar. The slime was of a pitchy substance, similar probably to bitumen. *See* Architecture.

BABYLONIAN ARCHITECTURE. In commencing this article, we must premise that we cannot pretend to any detailed description, as the materials for such an undertaking are almost entirely wanting. An account of this style of architecture must needs be very imperfect, when the very situation of the ancient Babylon remains uncertain. This once vast city, the metropolis of one of the great empires of the world, is now but one mass of undistinguishable ruins.

Owing to the interest belonging to so ancient and powerful an empire, much pains have been taken in the examination of the remains of the city, but so great is the confusion, that it has hitherto baffled the exertions of travellers to determine with certainty the situation and extent of any of the buildings mentioned by ancient authors: among the more successful of our modern travellers, we may especially mention the names of Rich and Ker Porter; and among the ancients, those of Herodotus, Strabo, and Diodorus. We shall proceed to give an account of the city as described by the latter class of writers.

Herodotus in his usual circumstantial manner, gives us a very exact and lengthened description. According to his account, the city was of a quadrangular form, four hundred and eighty stadia in circuit, divided into two districts by the river Euphrates: it was defended on all four sides by a deep trench and wall, of which the following is the method of construction. In the first place, the earth was excavated to form the trench, and, as it was dug up, was carried in masses of convenient size for bricks to the furnace, and there burnt; when this process was complete, the bricks were employed in lining the sides of the ditch, and erecting the superincumbent wall: the work was cemented together by bitumen, and bonded at every thirtieth course by layers of reeds. The wall on each side was a hundred and twenty stadia in length, fifty royal cubits in thickness, and two hundred in height; on the top, and on each side of it, was erected a row of houses of one story in height, facing each other, and leaving a space or roadway between them, wide enough to allow four horses to be driven along it abreast. Where the outer walls met the river, a return wall was carried along each opposite bank to fortify the city against attacks from this quarter, and behind this again another, but of smaller dimensions. In the four walls surrounding the city, were a hundred apertures or entrances closed by means of brazen gates, from each of which was continued a street to the corresponding ones on the opposite side, intersecting the roads which led from the transverse walls at right angles. Where the streets met the return wall along the banks, an opening was made down to the river, provided with brazen gates. The city was filled with houses of three and four stories in height; and among the most remarkable buildings, were the temple of Belus and the palace, one in each of the principal divisions on either side of the Euphrates. The former is a very remarkable building on account of its supposed connection with the tower of Babel mentioned in the Mosaical account of the colonization of the earth. Herodotus gives the following description:—The tower was of a square plan, surrounded by a wall of similar form, having each of its sides two stadia in length; the sides of the structure itself were only half this length, or one stadium. Our author does not give the height, but he states that the tower consisted of eight tiers, which gave to it the appearance of being composed of eight towers, placed one above the other; but this in reality was not the case; such resemblance being occasioned by an inclined platform winding round outside the building, and thereby making eight revolutions: this platform formed the only means of ascent. About halfway up the incline, was

a resting-place, and at the highest extremity a large temple dedicated to the god Bel, or perhaps Baal: there was another chapel in this building, containing an image of the god, of which we have no particular description.

Our historian further relates, that Nitocris having temporarily diverted the waters of the Euphrates by a course outside the city, embanked a part of the river, and made a descent into it from each of the gates in the return wall. This embankment was constructed of baked bricks in the same manner as the walls; a different material, however, was used by this queen in the construction of a stone bridge, or perhaps we should more correctly say piers of a bridge, as the roadway was formed of horizontal timbers, laid, as seems probable, from pier to pier. The beams were taken up at night, thus forming a kind of draw-bridge. In the piers, hewn stones were employed, which were securely connected together with iron and lead. Another remarkable work of this reign, was the erection of a building over the principal gates, to be used as a place of sepulture.

Thus far Herodotus; later authors differ from him in several particulars, still however preserving the same general account. Diodorus considerably diminishes the size of the outer wall, both in length and height, but the difference in the latter is easily accounted for, as he relates their condition as they appeared after the time of Darius Hystaspes, who reduced the height to fifty cubits. Strabo also gives the circuit of the wall at three hundred and eighty-five stadia. Diodorus further makes mention of two palaces, one on each side of the river, and connected by means of a bridge above and a tunnel below; he gives the circuit of the new palace as sixty stadia, that of the old thirty stadia; the new palace was surrounded by circular walls, enriched with decorations of sculptured animals, painted in colours on the bricks, and afterwards burnt in. The connecting tunnel our author states to have been vaulted, being twelve feet in height, and fifteen broad. This palace also contained the hanging gardens said to have been built by Nebuchadnezzar for his wife the Median Amytis. The gardens, occupying a space of ground four hundred feet square, consisted of terraces built one above the other until they reached a height equal to that of the outer walls of the city; the terraces being supported on piers and arches, as stated by Strabo, over which were laid large flat stones, sixteen feet long by four in breadth, and above those a layer of reeds mixed with bitumen, covered with two courses of bricks in cement. The extreme covering consisted of thick sheets of lead, on which was placed the mould for the garden. The spaces between the terraces were formed into magnificent apartments, and on the highest terrace was a pump, by means of which a supply of water was raised from the Euphrates to irrigate the gardens. The ascent to the top was by steps ten feet in width. Strabo gives us one additional particular respecting the tower belonging to the temple of Belus, namely, the height, which he states to be one furlong; according to Wesseling's reading, however, this particular is given by Herodotus.

Such is the description afforded by the ancients; let us now turn to the investigations on this subject by modern travellers, and in doing so we shall take the liberty of laying before our readers the account given by Mr. Rich, who has examined the ruins of this city with perhaps greater care than any other person. We must premise, that the site of the ancient city is a matter of dispute, but is allowed to be situate somewhere in the neighbourhood of Hillah and Mohawill. This position has been determined upon on account of the mounds and heaps of ruins which are found dispersed about this quarter, on or near the banks of the Euphrates.

"The ruins of the eastern quarter," says Mr. Rich, "commence about two miles above Hillah, and consist of two large masses or mounds connected with and lying north and south of each other, and several smaller ones which cross the plain at different entervals. These ruins are terminated on the north by the remains of a very extensive building called the Mujelibé, from the south-east angle of which proceeds a narrow ridge or mound of earth wearing the appearance of having been a boundary wall. This ridge forms a kind of circular enclosure, and joins the south-east point of the most southerly of the two grand masses. The river-bank, on the south-west of the tomb of Amram, is skirted by a ruin extending nearly eight hundred yards; it is for three hundred yards forty feet perpendicular; a little above this is a piece of ground formerly the bed of a river; here earthen vases with bones were found. From the east angle of the ruin on the river bank, commences another mound similar to that first mentioned, but broader and flatter; this mound is the most southerly of all the ruins.

"On taking a view of the ruins from south to north, the first object that attracts attention is the low mound connected with the ruin on the south-west of the tomb of Amram: on it are two small walls close together, and only a few feet in height and breadth. This ruin, which is called Jumjuma, and formed part of a Mohammedan oratory, gives its name to a village a little to the left of it. To this succeeds the first grand mass of ruins, which is 1100 yards in length, and 800 in its greatest breadth; its figure nearly resembles that of a quadrant; its height is irregular; but the most elevated part may be about fifty or sixty feet above the level of the plain, and it has been dug into for the purpose of procuring bricks. Just below the highest part of it is a small dome in an oblong enclosure distinguished by the name of Amran Ibn Ali. On the north is a valley of 550 yards in length, the area of which is covered with tussocks of rank grass, and crossed by a line of ruins of very little elevation. To this succeeds the second grand mass of ruins, the shape of which is nearly a square of 700 yards length and breadth, and its south-west angle is connected with the north-west angle of the mounds of Amran by a ridge of considerable height, and nearly 100 yards in breadth.

"Not more than 200 yards from the northern extremity of this mound is a ravine, hollowed out by those who dig for bricks, in length 100 yards, and 10 feet wide by 40 or 50 deep. On one side of it a few yards of wall remain standing, the face of which is very clean and perfect, and appears to have been the front of some building. Under the foundations, at the southern end, an opening is made, which discovers a subterranean passage, floored and walled with large bricks laid in bitumen, and covered over with pieces of sandstone a yard thick and several yards long; the weight above has been so great as to have given a considerable degree of obliquity to the side-walls of the passage; the opening is nearly seven feet in height, and its course is to the south. The superstructure over the passage is cemented with bitumen, other parts of the ravine with mortar, and the bricks have all writing upon them." The souterrain widens considerably as you proceed farther. This passage seems to form part of the *kasr*, or palace, and may have been perhaps the tunnel alluded to by ancient authors. The principal portion of this ruin, to which alone the term *kasr* is applied at present by the natives, is situate a little to the west of the ravine, and presents a remarkably fresh appearance, insomuch so, that Mr. Rich was not willing, until after a very close inspection, to allow its claims to being considered an original Babylonian remain. "It consists," says he, "of

several walls and piers, which face the cardinal points, eight feet in thickness; in some places ornamented with niches, and in others strengthened by pilasters and buttresses, built of fine burnt brick still perfectly clean and sharp, laid in lime cement, of such tenacity that it is almost impossible to extract a brick whole. The tops of these walls are broken, and may have been much higher; on the outside they have in some places been cleared nearly to the foundations; but the internal spaces formed by them are yet filled with rubbish, in some parts almost to the summit. One part of the wall has been split into three parts, and overthrown as if by an earthquake; some detached walls of the same kind, standing at different distances, show what remains to have been only a small part of the original fabric; indeed, it appears that the passage in the ravine, together with a wall which crosses its upper end, were connected with it.

"A mile to the north of the *kasr*, or palace, five miles from Hillah, and 950 yards from the river-bank, is a ruin called the *Mujelibè*, meaning *the overturned;* its shape is oblong, and its height, as well as the measurements of its sides, irregular. The sides face the cardinal points; the northern is 200, the southern 219, the eastern 182, and the western 186 yards in length; and the elevation of the south-east, or highest angle, is 141 feet. The western face, which is the least elevated, is the most interesting, on account of the appearance of building it presents. Near the summit of it appears a low wall, with interruptions, built of unburnt bricks mixed up with chopped straw, or reeds, and cemented with clay-mortar of great thickness, having between every layer a layer of reeds; and on the north side are also some vestiges of a similar construction. The south-west angle is crowned by something like a turret, or lantern: the other angles are in a less perfect state, but may originally have been ornamented in a similar manner. The western face is lowest and easiest of ascent; the northern the most difficult. All are worn into furrows by the weather; and in some places, where several streams of rain-water have united together, these furrows are of great depth, and penetrate a considerable way into the mound. The summit is covered with heaps of rubbish, in digging into some of which, layers of broken burnt brick, cemented with mortar, were discovered, and whole bricks with inscriptions are sometimes found. The whole is covered with innumerable fragments of pottery, brick, bitumen, pebbles, vitrified brick, or scoria, and even shells, bits of glass and mother-of-pearl. In the northern face of the Mujelibè, near the summit, is a niche, or recess, high enough for a man to stand upright in, at the back of which is a low aperture leading to a small cavity; whence a passage branches off to the right, sloping upwards in a westerly direction till it loses itself in the rubbish." Receiving intimation that human remains had been discovered near this spot, our traveller commenced a strict investigation, and after excavating to some depth through a hollow pier, formed of fine bricks laid in bitumen, and in size sixty feet square, he met with several antiques, amongst which were a number of earthen vessels, some thin and highly glazed. Prosecuting his labours still further, another passage was laid open; this cavity was narrow, about ten feet high, composed of both burnt and unburnt bricks, the latter with a layer of reeds between every course, except the two lowest, where they were laid in bitumen. In this passage Mr. Rich discovered a wooden coffin containing human remains, which presented the appearance of being of great antiquity. To the north and west of this mass of ruins, and at about 70 yards distant from it, runs a low mound, which may have formed an enclosure round the whole.

The only ruin of any consequence to be found on the western side of the Euphrates is that which is termed by the Arabs the *Birs Nemroud*, and by the Jews *Nebuchadnezzar's Prison;* it is situate about six miles to the south-west of Hillah, and is perhaps the most remarkable of all the ruins. Mr. Rich gives us the following description:—"The Birs Nemroud is a mound of an oblong form, the total circumference of which is 762 yards. At the eastern side it is cloven by a deep furrow, and is not more than fifty or sixty feet high; but at the western side it rises in a conical figure to the elevation of 198 feet, and on its summit is a solid pile of brick, thirty-seven feet high by twenty-eight in breadth, diminishing in thickness to the top, which is broken and irregular, and rent by a large fissure extending through a third of its height. It is perforated by small square holes disposed in rhomboids. The fine burnt bricks of which it is built have inscriptions on them; and so excellent is the cement, which appears to be lime-mortar, that it is nearly impossible to extract one whole. The other parts of the summit of this hill are occupied by immense fragments of brickwork of no determinate figure, tumbled together and converted into solid vitrified masses, the layers of brick being perfectly discernible. These ruins stand on a prodigious mound, the whole of which is itself a ruin, channelled by the weather, and strewed with fragments of black stone, sandstone, and marble. In the eastern part, layers of unburnt brick, but no reeds, are to be seen. In the north side may be seen traces of building exactly similar to the brick pile. At the foot of the mound a step may be traced scarcely elevated above the plain, exceeding in extent, by several feet each way, the true or measured base; and there is a quadrangular enclosure round the whole, as at the Mujelibè, but much more perfect, and of greater dimensions. At a trifling distance, and parallel with its eastern face, is a mound not inferior to that of the kasr in elevation, but much longer than broad; on the top of it are two *koubbès*, or oratories: round the Birs are traces of ruins to a considerable extent."

Having thus given a description of the ruins as they now exist, it remains to determine the identity between them, and the buildings mentioned by ancient authors. On this subject great differences of opinion exist; the chief difficulty arising from the almost entire absence of any vestiges of building on the western side of the Euphrates: this it has been attempted to obviate in various ways. Major Rennell, the author of a "Geography of Herodotus," is of opinion that the river has left its original bed, and formed a new channel for itself, which, he says, is a common occurrence in alluvial tracts of land, such as that upon which Babylon was situate; he supposes the ancient course of the river to have been between the Kasr and Mujelibè. In favour of this supposition, he quotes the words of Mr. Rich, where he says that the valley on the north of the Amran Ibn Ali is covered with tussocks of rank grass;—this, Major Rennell conjectures to have been the bed of the river. In opposition to this opinion, Mr. Rich states, that there are no sufficient grounds for supposing the river to have taken this course, but rather that the buildings seem entirely to preclude such idea; besides, he adds, every occasion was made use of to prevent the alteration in the course of the Euphrates in this neighbourhood; the possibility of such an occurrence was obviated by the artificial canals and cuts which were so numerous in this part of the country. He further accounts for the existence of the tussocks of rank grass, by the circumstance of the river occasionally overflowing its banks, and on its subsidence, leaving some portion of its waters in the hollows; this appears, we must confess, in some degree to

invalidate his former argument; it does seem, however, somewhat premature to suggest any material alteration in the course of the Euphrates, if difficulties can be accounted for by any other method; if any alteration is allowed to have taken place, it seems more reasonable to suppose the original course to have been through the ravine to the west of the ruins, especially as a number of bones have been found at this spot. The difficulty respecting the position of the river, however, is principally owing to Major Rennell's considerably contracting the dimensions of the city: he considers the statements of ancient authors respecting its magnitude as merely fabulous; but seemingly without any other reason than their improbability, or rather inaptitude, to our present notions of a city. If, however, present experience were to be universally applied, we should, with equal justice, deny the existence of many erections of which we have ocular demonstration, for instance, of the Pyramids and Sphinxes of Egypt. It is true that the circuit of Babylon, as given by ancient authors, is immense, but it is not entirely unaccounted for; for Quintus Curtius tells us, that nearly one-half of the city was occupied in gardens and other cultivated lands, and not, as modern cities, composed almost entirely of houses. Internal evidence also respecting the truth of his statement, is furnished by Herodotus, when he relates that, at the capture of Babylon by Cyrus, the inhabitants of the interior parts were not aware of what was taking place until some time after the circumstances occurred. If we allow the account of the ancients to be correct in this respect—and indeed we see little reason to the contrary—our difficulty in determining the localities of the ancient city will be considerably diminished; as we shall then be able to discover at least some remains on both sides the Euphrates, though not so great a number on the western side as we may have been led to expect.

Another mistake which, in our opinion, Major Rennell has been led to make, is the determining, at the very commencement of his inquiry, the site of the temple of Belus. Whether the position he has assigned it be the correct one, is another question; all that we suggest at present is, that such allocation is, in this case, premature; it at once puts a limit to free inquiry, as it determines what must be the relative position of every other edifice. Mr. Rich, on the other hand, commencing the subject entirely afresh, and taking a more comprehensive view of the matter, arrives at a different conclusion; he gives it as his opinion that the Birs Nemroud has the better claims to be considered as the ancient tower. In favour of this opinion it may be observed, that it would at once obviate the difficulty we have in reconciling the statement of the ancients, respecting the location of the palace and temple of Belus on opposite sides of the river, with the discoveries of the moderns. But, it may be objected, Herodotus states that these edifices were in the centre of either division of the city: now the word used by that author is ἐν μέσῳ, which, we think, may be translated literally enough by *in the midst*, or even by the preposition *within*, and certainly more correctly so than by *in the centre*. Should, however, any objection be made to this translation, we would argue that in so large a space, our author may be allowed a little latitude in cursorily describing the position of principal buildings in the plan of so vast a city. Moreover, we have further evidence in favour of this assumption, in the remarkable similarity of the remains to the descriptions we have of the old edifice. Before proceeding further, we may as well get rid of one objection which may be urged in opposition to the statements we are about to make: the plan of the remains is an oblong, and not a square, as stated by Herodotus; now, we must remind our readers that, although the more common reading states the building to have been of a square plan, yet that this reading has been with good reason objected to, and has been altered by Wesseling in his edition; we do not think, therefore, that this objection ought to have much weight. To return:—The ruins present the appearance of a building of 762 yards periphery, surrounded by an outer wall; the present height of the building is 235 feet, in which space Mr. Rich discovered traces of three different stages, similar to those described by Herodotus; and Mr. Buckingham, a later traveller, in the same space, thinks four stages clearly discernible. Now, if we add the same height for other four stages to complete the number of eight as given by Herodotus, we shall find the total height of the building equal to 470 feet, or about a stadium, the height given by the ancients. This we think amounts to almost conclusive evidence for the supposition of Mr. Rich; further, however, the appearance of the kasr answers very well to the description of the ancient palace, and one part is especially to be noted for its resemblance to the hanging-gardens: the hollow shaft mentioned amongst the discoveries of Mr. Rich, is very similar to the hollow piers supporting the terraces as described by Strabo. The author, from whose narrative we have so copiously extracted, supposes the whole of that mass of ruins on the eastern bank of the river, enclosed by circular walls, to have formed a part of the ancient palace, for, says he, it is manifest that the palace was not merely a single edifice, but consisted of a number of buildings, surrounded probably by an outer wall; and this supposition appears very probable, especially as it related that the hanging-gardens were within its precincts. Major Rennell, however, while he assigns the kasr especially to the palace, and the Mujelibè to the temple of Belus, considers the circular rampart which encloses them as an erection of modern date. In opposition to this notion, Mr. Rich suggests that we have no accounts of any later erection on this spot, whereas Diodorus expressly states that the palace was surrounded by circular walls. Besides this, he brings forward what he considers a convincing proof of its antiquity, which is this—that wherever bricks engraved with the arrow-headed characters are here found, they are all placed with the engraved sides *downwards*. This circumstance he considers sufficient evidence of the walls having been erected at a very early period; for during his extensive researches, he observed that in the old buildings the bricks were invariably laid in this particular position; in later erections, where the old materials had been made use of, this peculiarity had not been attended to.

The question respecting the identification of the remains with the ancient buildings, has elicited considerable information on the subject, and has been very ably treated by many learned men. A variety of opinions has arisen in consequence of the difficulties with which the subject is attended, none of which, however, have been broached without good reason: we are inclined to give the preference to Mr. Rich's suggestions, but at the same time we must confess that the other views taken of this case are worthy of most careful consideration.

We have extended the present article to so great a length, on account of the interest which must necessarily appertain to a style of building of such early date. Much as the originality of the various modes of architecture has been discussed, and although many weighty reasons have been alleged in proof of the superior antiquity of some few of the other styles, of, for instance, the Cyclopean, the Egyptian, and the Indian; yet it seems to us that the Babylonian has a greater claim to originality than any other. As far as we can discover from historical records, it is very evident that the first great empire established in the world was that of Babylon. The

account given in the sacred history, and which is confirmed, as far as may be, by all other historical records, tells us that the first great kingdom was founded, and the first city built, by Nimrod, a name which has been preserved by tradition even up to the present time, and is still held in especial reverence; thus proving, at least, the existence of such a person, and his pre-eminent usefulness to the city and people of Babylon. It may be said, we are well aware, that this is mere tradition; yet we cannot allow that tradition, even when it appears in its most absurd colouring, is entirely to be despised: we cannot account for the promulgation of any legend that has absolutely no origin, such an idea is indeed absurd; every traditional story must have some real, tangible source, and reality cannot but be truth; such stories may have been embellished, or, if you please, disfigured by fiction, but they must have their foundation at least in fact.

Many persons, we know, are very unwilling to assign much credit to the Mosaical narrative; but we think we are fully entitled to claim for it equal authority with that of most of the other historians who make any reference to the occurrences of so early a date, especially as its author is allowed to be the earliest historian, and for this reason must have lived closer to, and have been, we should suppose, more competent to relate the occurrences of, the times to which he refers. Claiming so much authority, then, for our author, we would beg our readers to allow a fair modicum of credit for his sketch of the early history of Babylon; we say sketch, for it has no higher pretensions, nor could we naturally expect any detailed history from an historian living eight hundred years posterior to the period whose history he is relating. We may here apply a very sensible remark made by Rollin in speaking of the history of this empire: "where," he says, "certainty is not to be had, I suppose a reasonable person will be satisfied with probability." It is true that Moses does not expressly state that Babylon was the first city, but we have every reason short of certainty to believe that he intended to imply as much. In giving the genealogy of Noah's descendants, he stops at the name of Nimrod, to tell us that "he began to be a mighty one in the earth;" which expression, if it does not indeed say in so many words that he was the first one who obtained superiority, may, at least, when taken in connection with all other attendant circumstances, imply quite as much; and it is further told us, that "the beginning of his kingdom was Babel." Further on in the narrative, we are told where and what this Babel was, as well as when its erection took place, namely, in the time of Peleg, the fifth from Noah, probably at some particular period of his life; perhaps shortly after his birth—for, "in his days was the earth divided:" the causes of this division, and the particulars of the building of Babel, are related as follows: "The whole earth was of one language, and of one speech; and it came to pass, as they journeyed from the east, that they found a plain in the land of Shinar; and they dwelt there. And they said, Go to, let us build us a city, and a tower whose top may reach unto heaven; and let us make us a name, lest we be scattered abroad upon the face of the whole earth. And the Lord came down to see the city and the tower which the children of men builded. And the Lord said, Behold, the people is one, and they have all one language; and this they begin to do: and now nothing will be restrained from them, which they have imagined to do. Go to, let us go down, and there confound their language, that they may not understand one another's speech. So the Lord scattered them abroad from thence upon the face of all the earth: and they left off to build the city; therefore is the name of it called Babel." To any one reading this account, there can, we think, be little doubt, that it was the writer's intention to signify, that Babel was the first permanent erection of any significance, that it was the joint erection of all men then in existence, and also that it was the origin of the city afterwards known by the name of Babylon.

It now rests with us to shew the identity of the existing remains, and of the city erected by Nimrod, and in this case again we must rest content with probability. Now it seems universally allowed that some part of the mounds are identical with the ruins described by Herodotus; how large a portion this may be we do not pretend to assert, but we have already stated that Mr. Rich includes a large proportion of the existing remains. We have only in continuation to give our reasons for considering the buildings described by Herodotus as identical with those referred to by Moses. In the first place, then, the former writer seems to speak of Babylon as a very ancient city in his time, and mentions it as a remarkable occurrence that the tower of Belus was then standing; he speaks of a long line of kings, and relates that Semiramis made some improvements in the city, thus implying that the city had been erected some considerable period before her reign. This queen is supposed to have lived from twelve hundred to two thousand years before our era, thus bringing the erection of the city close upon that of Babel, as recorded in the Scriptures. Another proof of identity is seen in the nature of the materials used in the buildings, and in the manner of their erection, and in these matters the two accounts perfectly coincide. Moses, in that part of his narrative already quoted, says,—"And they said one to another, Go to, let us make brick, and burn them thoroughly; and they had brick for stone, and slime (bitumen) had they for mortar." The account of Herodotus, although of a more detailed description, agrees in every particular with that just given;—we need not refer to it here, as it has already been given in full. Again, is there not every reason to believe that the tower of Babel and that of Belus are one and the same edifice? Herodotus evidently looks upon the tower as of very remote origin, as the oldest building in Babylon; indeed, it seems to be a building remarkable on many accounts, standing out distinct from all surrounding edifices, as well by its great height, as by its unusual construction; it is apparently looked upon by all those who have seen it with a kind of awe, as though its erection, and every other thing connected with it, was entirely beyond their comprehension.

Taking all these circumstances into consideration, we venture to assert there will be considered sufficient evidence to satisfy any reasonable person of at least the probable identity between the buildings referred to in the Mosaical narrative, and the ruins now in existence, as described by recent travellers.

The remains of this great city do not afford us an opportunity of stating, with any preciseness, the style, so to speak, adopted in its architecture. The buildings generally are rude, and show but little evidence of constructive science; they are of gigantic proportions, and very massive, on which quality they rely chiefly for their strength; their construction is indicative of greater antiquity than that of the Indian or Egyptian styles, for, whereas, in the latter, we find detached columns, in the Babylonian we see no traces of them; indeed, the construction is altogether much heavier and of more barbarous appearance. The edifices were almost universally composed of bricks, of which there were various qualities, some dried in the sun, others baked in a kiln; there was also a finer sort, the clay of which, previous to being burned, was mixed up with chopped straw or reeds, and these

last seem to have been used for facing walls built of the commoner sort of brick; there is one peculiarity about them, however, which may not be overlooked, and this is the indentation on their surface of certain marks arranged in parallel lines, termed arrow or nail-headed characters. These marks are supposed to represent letters, or words; but, although much learned labour has been given to the task, their signification has not been discovered, nor, indeed, the method of deciphering them determined upon: similar inscriptions have been found at Persepolis and Susa, also on some rocks near Argish, in Armenia, and sometimes, but very rarely, in Egypt. To return:—The bricks were cemented together with hot bitumen, but were sometimes laid in clay, and at others in lime-mortar, and bonded together by straw, or reeds. The walls, as we have previously mentioned, were of great thickness, strengthened at intervals by pilasters, or buttresses, which were sometimes adorned with niches. Columns were not made use of, the nearest approach to the idea being found in the large hollow piers which supported the hanging-gardens. The principle of the arch does not seem to have been understood, although some authors have stated a contrary opinion; no examples of its application have been found, and the fact of inconveniently large masses of sandstone having been made use of in places where the arch would have been most applicable, as in the case of the passage described by Mr. Rich, is, we think, a conclusive argument that the principle was not known. (For further information on this subject we refer to the article on Arch.) The working of metals seems to have been in extensive practice, as Herodotus tells us that all the gates were made of brass.

Although externally their buildings were of this rude description, the Babylonians evinced some taste in the interior decorations. Among other modes of ornamentation, they made use of coloured bricks. These bricks were painted while in a moist state, and the colours afterwards burnt in; the subjects represented were usually animals, standing out in relief from the general surface, and richly painted in their natural colours. Statues likewise formed a very usual mode of decoration

We have now only to notice that peculiar building, the Birs Nemroud, of which we have elsewhere given a description; it will, therefore, be unnecessary to enter into detail here; we would only beg of our readers to notice its peculiar form, that of a pyramid, and remark, that if this tower be allowed to be the first erection of importance, it will very readily account for the circumstance of that form being so universal in other styles of very early date. This kind of erection is found, not only in Egyptian and Indian architecture, but also in other styles, whose connection with the Babylonian is not so easily accounted for; and Humboldt, in speaking of a pyramidal mass of ancient Mexico, says,—"It is impossible to read the descriptions which Herodotus and Diodorus Siculus have left us of the temple of Jupiter Belus, without being struck with the resemblance of that Babylonian monument to the teocallis of Anahuac." It is true that the pyramidal is that form which would most naturally suggest itself to men unacquainted with the contrivances of art, but we venture to think, that the suggestion we have above thrown out, is not entirely unworthy of the attention and consideration of the curious.

Having at length arrived at the conclusion of this article, we would apologize for having extended it to a length which some may be inclined to think unreasonable; when, however, the interest attaching to such ancient remains, and the comparatively slight attention the subject has hitherto obtained, are considered, we feel confident of receiving the pardon of our readers.

BACK, the side opposite to the face, or breast. In a recess, upon a quadrangular plan, the face is that surface from which the recess is made: therefore the back is the surface which has the two adjacent planes, called the sides, elbows, or gables. When a piece of timber is fixed in a level or inclined position, the upper side is called the back, and the lower, the breast: thus the upper side of the hand rail of a stair is called the back. The same is to be understood with regard to the curved ribs of ceilings, and the rafters of a roof: their upper edges are always called the backs.

BACK of a Chimney. *See* Chimney.

Back of a Hand-Rail, is the upper side of it. Its formation is shown under the articles Stairs and Hand-Railing.

Back of a Hip-Rafter. *See* Hip-Roof.

Back Lining of a Sash-Frame. *See* Sash-Frame.

Back of a Rafter, is the upper side of it, in the sloping plane of the one side of a roof. The manner of forming the back is shown under Rafter. *See* also Roof, in Carpentry.

Back-Shutters, or Back-Flaps, are additional breadths hinged to the front shutters, necessary in closing the aperture completely, when the window is required to be shut. When the aperture is open, or when light is required, the back-shutters are concealed in the boxing by the front-shutters. Back-shutters are generally made thinner than front-shutters, and framed with bead and butt.

Back of a Stone, the side opposite to the face, which is generally rough.

Back of a Window, in joinery, is the board, or wainscoting, between the sash-frame and the floor, joining upon the two elbows, and forming a part of the finish of the room in which it is placed. It is in general parallel to the face of the wall, or to the glass, or sash-frame, and, when framed, it has commonly a single panel with mouldings on the framing, corresponding to the doors, shutters, elbows, soffits, &c., in the same apartment in which it is placed. The framing of the back and the skirting are generally in the same plane, or flush, and the upper edge of the skirting is wrought with a bead, which conceals the joint between the lower edge of the rail, and the upper edge of the skirting below it. The top edge of the upper rail is generally capped with a slip of timber, level on the top, beaded on the front edge, and tongued into the sash-frame. The capping bead is returned upon the two elbows, and has the most prominent part of the convexity flush with the framing of the elbows, as well as that of the back. Framed backs and elbows for good houses are generally finished at one and one-eighth inch thick.

Backing of a Rafter, or Rib, the formation of an upper or outer surface, so as to range with the edges of the ribs or rafters, on either side of it. *See* also Ranging, or Edging.

The formation of the inner edges of the ribs for lath-and-plaster ceiling, is sometimes improperly called backing.

Backing of a Wall, is the building which forms the inner face of the wall, or, the act of building the inner face. This term is opposed to facing, which is the outside of the wall. In stone walls the backing is generally rubble, though the facing be ashlar.

BADIGEON, a mixture of plaster and free-stone, well sifted, and ground together: it is used by statuaries to fill up the small holes, and repair the defects in stones of which their work is made. The term is also used by joiners, for a composition of saw-dust and strong glue, with which the chasms of their work are filled. Joiners likewise use for this purpose, a mixture of whiting and glue. When this is used, the filling-in should remain till quite hard, otherwise,

when it is plained or smoothed off, it will shrink below the surface.

BAGNIO, a *bath*. The word is applied by us to houses which have conveniences for bathing, sweating, and otherwise cleansing the body. Bagnio, in Turkey, is a general name for the prisons where their slaves are kept. So called from the baths they contain.

BAGUETTE, a small astragal moulding, sometimes carved and enriched with pearls, ribbands, laurels, &c. When the baguette is enriched, it is called *chaplet*, and when unornamented, *bead*.

BALBEC, or BAALBEC, a famous city of Syria, celebrated by the Greeks and Latins under the name of Heliopolis, the city of the sun, or Baal. It was surrounded with walls, which were flanked with towers at regular intervals. The principal remains consist of the great temple, a smaller one, called by Mr. Wood the most entire temple, a circular temple of a singular construction, and a Doric column standing alone. The longitudinal direction of the great and most entire temples is east and west. Before the entry to the great temple are two courts and a portico, which face eastwards. After passing the portico, we come to an hexagonal court, surrounded with columns and apartments; we thence enter a quadrangular court, the area of which is also surrounded with columns: on the north or south side of this court are seven apartments, or exhedræ; five are rectangular on the plan, one stands in the middle, having a semicircular exhedra on each side of it. These were probably lodging rooms for the priests. At the other extremity of this court, upon the south, are columns of a colossal magnitude, being the remains of the peristyle of the temple. The shafts are twenty-one feet eight inches in circumference; and the entire height of the columns fifty-eight feet.

The columns are all joined with iron cramps, and without cement, which is nowhere used in these edifices, but the surfaces are so close that there is hardly room for the blade of a knife to be inserted between them. The stones which compose the sloping wall are of enormous size. On the west the second course is of stones from twenty-eight to thirty-five feet long, and nine feet in height: and at the north angle, over this course, are three stones, which occupy one hundred and seventy-five feet seven inches. The shafts of the columns of the great temple consist each of three pieces which are joined with iron pins about one foot long, and one foot diameter. Most of the bases had two sockets, one circular, and the other square. Greek and Roman authors are entirely silent as to these astonishing ruins.—(*Ruins of Balbec, by Wood and Dawkins.*)

BALCONY, (from the French *balcon*,) an open gallery projecting from the front of a building, surrounded with a rail or balustrade, of various devices, and supported by cantalivers, brackets, or columns. It is made of wood, stone, sometimes of cast-iron, and sometimes also of bar-iron fashioned into crail-work, of various fanciful figures.

Balconies are generally made on a level with the sills of the windows of the first floor; sometimes every window in the range has a separate balcony, each of which is convex to the street. When there is but one, it is generally placed in the middle of the length of the front, or extends the whole length of the front. Sometimes a portico or porch is surmounted with a balcony; in this case the balustrade may be of stone, as well as of iron, or wood. When balconies are used, the windows are generally brought down to the floor, without adding any additional breadth to the aperture. *See* BALUSTRADE.

BALDACHIN, (from the Italian *baldacchino*,) a piece of architecture in the form of a canopy, supported with columns, and serving as a covering to an altar. The baldachin supplanted the ciboreum, which was of the same nature; but whereas the former was a canopy, the latter was in form similar to the monoptral temple described by Vitruvius.

The baldachin in St. Peter's at Rome is of bronze, and was made by Bernini. The dais, or covering, is supported on four large twisted columns of the Composite order, on pedestals of black marble. Above the columns are four figures of angels; at the top of the covering there is a cross, and below the entablature the fringe of the banner-like cloth of the portable baldachin has been imitated. The height is 125 feet 3 inches from the floor of the church to the summit of the cross, and the whole work is in the highest degree elegant and graceful.

BALECTION MOULDINGS. *See* BELECTION MOULDINGS.

BALKS, large pieces of timber brought from abroad in floats: their scantling being from five to twelve inches square. Balks, in some parts of England, are used for the summer-beams of a building, also for the poles or rafters laid over out-houses, or barns.

BALLOON, (from the French *ballon*,) a crowning of a globular form, used by way of an acroter to a pediment, pillar, or the like. That on the top of St. Peter's at Rome is of brass, about eight feet diameter, and placed at the height of sixty-seven fathoms.

BALL-FLOWER, an ornament resembling a ball placed in a circular flower, the three petals forming a cup round it; much used as an enrichment to mouldings, and otherwise in the decorated style of Gothic architecture.

BALLIUM, the space immediately within the outer walls of an ancient castle.

BALTHEI, bands, or girdles. This word is used by Vitruvius for some part of the Ionic volute. The balthei are supposed to be the mouldings which encompass the bolsters of the volutes.

BALUSTER, sometimes corruptly called BANISTER, a small kind of column or pillar belonging to a BALUSTRADE, (which *see*.) The various forms of Balusters given in the accompanying plate, are selected chiefly from Sir William Chambers, who has appropriated some of them to the orders of architecture, as their names express. The two last, denominated *Corinthian* and *Doric*, were designed by Mr. Nicholson, and their curve is found by an algebraic equation as in OVAL. Their general form is graceful, and their elegance may be preserved in any proportion; thus, suppose it were wished to have a very slender baluster made from the very stout one, here called DORIC; divide the length of the baluster required into ten equal parts, and the given baluster into the same number; draw lines on both, as ordinates; place the ordinates of the given baluster upon the respective lines of the one required, and through the extremities draw a curve, which will complete the baluster sought for.

BALUSTERS OF THE IONIC CAPITAL, the two lateral parts contained between each front and rear volute, called by Vitruvius, *pulvinata*.

BALUSTRADE, a range of small columns called balusters supporting a cornice, used as a parapet, or as a screen, to conceal the whole or a part of the roof. It is also sometimes used as a decoration for terminating the building. Balustrades are employed in parapets, on the margins of stairs, before windows, to enclose terraces, or balconies, by way of security, or sometimes to separate one place from another. In the theatres and amphitheatres of the Romans, the pedestals of the upper orders were always continued through the arcades, to serve as a parapet for the spectators to lean over; the lowermost seats next to the arena in the

amphitheatres, and those next to the orchestra in the theatres, were guarded by a parapet, or podium. The walls of ancient buildings generally terminated with the cornice itself, but often with a blocking course, or attic. In the monument of Lysicrates at Athens, the top is finished with finials composed of honeysuckles, solid behind, and open between each pair of finials; each plant or finial is bordered with a curved head, and the bottom of each interval with an inverted curve. Perhaps terminations of this nature might have been employed in many other Grecian buildings, as some coins seem to indicate; but this is the only example of the kind. The temples in Greece are mostly finished with the cornice itself; which was also the case with many of the Roman temples; and as there were no remains of balustrades in ancient buildings, their antiquity may be doubted: they are, however, represented in the works of the earliest Italian writers, who, perhaps, may have seen them in the ruins of Roman edifices.

When a balustrade finishes a building, and crowns an order, its height should be proportioned to the architecture it accompanies, making it never more than four-fifths, nor less than two-thirds, of the height of the order, not reckoning the plinth on which it is raised; as the balustrade itself should be completely seen at a proper point of view. Balustrades designed for use should always be of the height of the parapet walls, as they answer the same purpose, being nothing else than an ornamented parapet; this height should not exceed three feet and a half, nor be less than three feet. In the balusters, the plinth of the base, the most prominent part of the swell, and the abacus of their capital, are generally in the same straight line: their distance should not exceed half the breadth of the abacus, or plinths, nor be less than one-third of this measure. On stairs, or inclined planes, the same proportions are to be observed as on horizontal ones. It was formerly customary to make the mouldings of the balusters follow the inclination of the plane; but this is difficult to execute, and, when done, not very pleasant to the eye; though in ornamental iron work, where it is confined to a general surface passing perpendicularly by the ends of the steps, it has a very handsome appearance. The breadth of pedestals, when placed over an order, is regulated by the top of the shaft, the die being always equal thereto. When balustrades are placed upon the entablature of an order, over the intercolumns, or interpilasters, and the base and cornice of the balustrade continued, so as to break out and form pedestals over the columns, or pilasters, the breadth of the die of the pedestals should be equal to the breadth of the top of the shafts; and when there is no order, the breadth of the die never more than its height, and very seldom narrower: the dies of the pilasters may be flanked with half dies, particularly when the range of balusters is long.

BAND, a narrow flat surface, having its face in a vertical plane, as the band of the Doric architrave, and the dentil band, which is the square out of which the dentils are cut. The word facia, or plat band, is generally applied to broad members, as the facia of an architrave; and band, to narrow ones wider than fillets. Band is also the cincture around the shaft of a rusticated column.

Banded Column, is that which is encircled with bands, or annular rustics.

BANDELET, or Band, any flat moulding, or fillet. *See* Band.

BANKER, the stone-bench on which masons cut and square their work.

BANQUETING-ROOM, an apartment for entertainment, used among the Romans in the latter ages of the empire. In ancient times they supped in the atrium of their houses, but in after-times, magnificent saloons, or banqueting-rooms, were built for the more commodious entertainment of their guests. Lucullus, we are informed by Plutarch, had several very grand banqueting-rooms, and the Emperor Claudius had a very elegant one, named Mercury; but everything of this kind was outdone by the lustre of the still more celebrated banqueting house of Nero, called *domus aurea*, the house of gold, which, by the circular motion of its ceilings and partitions, imitated the revolution of the heavenly bodies, and represented the different seasons of the year, which changed at every service, and showered down flowers, essences, and perfumes on the guests.

BAPTISTERY, (from βαπτιζο, *to wash*,) a building, or apartment, designed for the administration of baptism.

In ancient times, baptism was performed by immersion, and the place for the purpose was a pond or stream; but about the middle of the third century, distinct or insulated houses were erected for the purpose. In 496, they were attached to the exterior sides of the church; and in the sixth century, they were brought within the church; but though there might have been two or more churches in one city, yet, in general, there was only one baptistery; and when it became fashionable to dedicate the churches, that to which the baptistery belonged was dedicated to St. John the Baptist. The baptismal churches in Italy were usually built near rivers and waters. In later times, the bishop of baptismal churches granted licenses to other churches to erect baptisteries, taking care at the same time to maintain his own jurisdiction over the people.

The baptistery was an octagon building, covered with a cupola roof, adjacent to the church, but not forming a part of it.

In the interior was a hall, sufficient to contain a great number of people, on the sides of which was a number of apartments; sometimes, instead of these apartments, rooms were added on the outside, in the manner of cloisters: in the middle of the hall was an octagon bath, which, strictly speaking, was the baptistery, and from which the whole building derived its appellation.

The most celebrated baptisteries are those of Rome, Florence, and Pisa; the most ancient is that of S. Giovanni in Fonte at Rome, said to have been erected by Constantine the Great. The plan of this building is octangular; the roof is supported by eight large polygonal pillars of porphyry under the cupola; in the centre of the floor is the bath, lined with marble, with three steps for descending into it: its depth is about thirty-seven inches and a half. The baptistery annexed to the splendid church of St. Sophia, at Constantinople, resembled the convocation-room of a cathedral; and was called *illuminatory*. In the middle was the bath, and around it were outer rooms for all concerned in the immersion.

The Baptistery of Florence stands opposite to the principal entrance of the cathedral. It is octangular in form, with a diameter of about one hundred feet. In the interior is a gallery, supported by sixteen large granite columns; the vaulting is decorated with mosaics, and on the pavement is a large circle of copper, with numerical figures, and the signs of the zodiac on it. The external façades are built of black and white marble, and the three great bronze doors are celebrated for the beauty of their bas-reliefs, and for the marble and bronze figures above them.

The Baptistery of Pisa is circular; its diameter is 116 feet; the walls are eight feet high, and the building is raised on three steps, and surmounted by a dome in the shape of a pear. This dome, which is covered with lead, is intersected by long lines of very prominent fretwork, terminating in another dome, above which is a statue of St. John. The proportions of the interior are admirable; eight granite

columns, placed between four piers, decorated with pilasters, are arranged round the basement story; these support a second order of piers, similarly arranged, on which rests the dome. In the middle of the baptistery, is a large octagonal basin of marble raised on three steps. *See* FONT.

BAR, a piece of wood, or iron, for fastening any kind of closure, as a door, or shutter. It is used as an additional fastening to a door, attached to the side, and movable to and fro upon the surface, so as to be inserted, or drawn out of the jamb, head, or sill, at pleasure; and is most commonly placed on the vertical edge of the door. Doors and shutters have sometimes bars so long as to be equal to the whole breadth of the aperture, or something more; and frequently made to turn upon a centre on the side of the door or shutter.

BARS FOR THE SHUTTERS OF WINDOWS, are frequently made with one or more joints, according to the number of shutters in the breadth of the window, and are fastened by means of bolts and fore-locks.

BARS OF A BOARDED DOOR, are pieces placed on the back, to which the boards are fastened; bars of this nature are more commonly called ledges.

BARS OF A SASH, are those slight pieces of wood or metal which divide the sash-light into two or more compartments, so as to reduce the large opening into smaller ones of convenient dimensions, suitable to the size of the panes of glass.

Those bars which stand in the intersection of two vertical planes, are called angle-bars. *See* ANGLE-BARS.

BAR-IRON. *See* IRON.

BAR-POSTS, are those which are fastened into the ground, forming the sides of a field gate, and are mortised so as to admit of horizontal pieces, called bars, which may be inserted easily or taken out at pleasure.

BARBACAN, or BARBICAN, in ancient fortifications, was an advanced work, which frequently covered the draw-bridge at the entrance of a castle. The term is likewise applied to the aperture in walls, called embrasures. *See* EMBRASURES.

BARBACAN, in architecture, is a long narrow canal, or opening, left in the walls for water to come in and go out by, when edifices are placed so as to be liable to be overflown; or to drain off the water from a terrace or the like.

BARGE-BOARDS, two boards attached to the gable ends of a roof, fixed near the extremity of the barge-course, and following the inclination of the roof, used for the purpose of protecting the under or stuccoed side of the barge-course from the weather. They are found most usually in old English houses, and being carved in most rich and elaborate patterns, add great beauty and picturesque effect to the buildings. They have been of late applied in many instances, where their utility seems to have been entirely misunderstood, and where, instead of protecting, they only serve as a dead weight to the building. The word is probably derived from an old Saxon term signifying *to shade* or *cover*.

BARGE-COUPLES, two beams mortised and tenoned together, for strengthening the building. The term is not much used.

BARGE-COURSE, that part of the tiling which projects over the gable of a building, and is made up below with mortar.

BARN, a covered building, for laying up and preserving all sorts of grain, hay, straw, &c. The situation of a barn should be dry and rather elevated, and on the north or north-east side of a farm-yard; but neither contiguous to the house, nor to any offices connected with it. Barns may be constructed of either stone, brick, or timber, which last may be wooden framing, covered with weather boarding; but whichsoever of these materials is used, holes should be left in the walls at intervals, or the doors and windows should have proper air-flights, so as to admit the ingress and egress of air freely. The gable-ends are best formed of brick or stone, on account of their solidity; the covering may either be thatch or tiles. In the walls of the front and rear of the building should be two large folding doors, for the convenience of carrying in and out a cart or waggon load of corn in sheaves, or any other bulky produce: these doors should be of the same breadth with the threshing-floor, to give more light to the threshers, and admit more air for winnowing the grain. Over the threshing-floor, and a little above the reach of the flail-poles, beams are often laid across, in order to form a kind of upper-floor, upon which the thresher may throw the straw or haulm; and on the out-side, over the great doors, it is convenient to have a large pent-house made, projecting sufficiently, so as to cover a load of corn, or hay, in case a sudden storm should come on before it can be housed, and also to shelter the poultry in the farm-yard from bad weather, or too great heat. The hay-barns should usually be constructed of wood, and not too close: they are sometimes formed in such a manner, as to be capable of being moved to different places by wheels or rollers. In grazing-farms, which do not afford a supply of straw for thatching, the stacks with movable roofs, erected on strong upright posts of wood, or what is sometimes termed Dutch barns, may be useful, as they may be raised or lowered at pleasure by screws and levers, so as to accommodate themselves to the quantity of hay, either in proportion to the crop or its consumption, while, at the same time, they are cheaper more airy, and less troublesome than close barns, in case of heating. The under-pinning of barns is best of stone or brick, which may be built to the height of about two feet above ground; the sides should be boarded, and the roof covered with straw or reeds; but those of the stables on its sides, with slate or glazed tile; because, as they must be more flat, the water which runs from the roof of the barn would injure most other coverings. At each end of the barn, and over the back-door, small doors, four feet high, should be fixed at the height of twelve feet from the ground: the two former for putting in corn at the ends, and the latter for filling the middle of the barn after the bays are full. All the bays should have a floor of clay or marl, and the threshing-floor should be laid with hard bricks, which will be suitable for all sorts of grain, except wheat or rye: for threshing these, it will be advisable to have planks of oak or red deal well fitted together, and numbered, to be laid down occasionally, and confined by a frame at their ends.

Barns should be placed upon a declivity, as by this means they are rendered more durable, less subject to vermin, and the grain can be kept more sweet and dry than on level ground: this situation also affords a commodious range of stalls for cattle.

The invention of the threshing machine has, in a great measure, altered the construction of barns, as, where they are made use of, they should be contrived chiefly with a view to the distribution of straw; the machines being built in the centre, with the grain-stacks adjoining them, in such a manner, that they may be supplied without the assistance of carts or horses. The barns, in these cases, need not to be so large, but they should have granaries provided in them, which may perhaps be most conveniently placed over the floors.

BARREL DRAIN, one constructed in the form of a hollow cylinder. *See* DRAIN.

BARROW, or TUMULUS, a hillock or mound of earth,

anciently raised over the body of a distinguished person. Barrows are considered as the most ancient sepulchral monuments in the world.

BAS-RELIEF. *See* Basso Relievo.

BASALT, a hard dark-coloured rock, of igneous origin, formed of columnar or stratified parts, very useful in building, paving, &c. Basalt, when calcined and pulverized, is an excellent substitute for puzzolana, in the composition of mortar: by undergoing these operations, it acquires the property of hardening under water.

BASE, in architecture, is the lowermost part of a body, consisting of one, or an assemblage of parts, taken in its altitude, being separated from its upper part, which is a naked or plain surface.

Base of a Room, is the lower projecting part, consisting of two portions, the lower of which is a plain board adjoining the floor, called the plinth, and the upper consists of one or more mouldings, which, taken collectively, are called the base-mouldings. The plinth in the best work is tongued into a groove in the floor, by which means, the diminution of breadth in the shrinking never shows any aperture, or cavity, between its under edge and the floor; and the upper edge of the plinth is rebated upon the base. Bedrooms, lobbies, passages, and staircases, are often finished without the dado and surbase, as also sometimes vestibules and halls. Rooms which have pavement floors, have their bases, in general, consisting of stone plinths, and wooden base-mouldings, which are not so liable to be broken as stone mouldings.

BASEMENT, the lowest story of a building, on which an order is placed, consisting of a base, die, and cornice. The choragic monument of Lysicrates is a beautiful example of an antique basement. In modern buildings, the height of the basement will vary according to the character of the edifice: it is proper, however, to make the basement no higher than the order of the next story, for this would be making the base of more importance in the composition than the body to be supported. If the cellar story is the basement, and if the height does not exceed five or six feet at the most, it may be plain, or with rustics, or formed into a continued pedestal; but if the basement is on the ground story, the usual manner of decorating it is with rustics, supported on a base and surmounted with a crowning string course: the base may be either a plain or moulded plinth; and the cornice may either have a plat-band or mouldings under it, or may form a cornice of small projection. The rustics are either of a rectangular or triangular section, supposing one of the sides of these sections to be a line extending across the front of the joints. The joints of the rustics may be from one-eighth to a tenth part of their height; the depth of the triangular joints may be half their breadth; that is, making the two planes by which they are formed a right angle; and the depth of the rectangular from one-fourth to one-third of their breadth. The ancients always marked both directions of the joints of the rustics, whereas the moderns employ not only the ancient manner, but sometimes make them with horizontal joints alone; the latter, however, represent rather a boarded surface than that of a stone wall, which must have two directions of joints.

The height of the string course should not exceed the height of a rustic with its joints; nor the plinth, or zocholo, be less than the height of the string course. When the basement is perforated with arcades, the imposts of the arches may be a plat-band, which may be equal to the height of a rustic, exclusive of the joint. When the string course is a cornice, the base may be moulded, the projection of the cornice being two-thirds of its height, so as to be less prominent than that which finishes the building. The height of the cornice may be about one-eighteenth part of the height of the basement, and that of the base, about twice as much, divided into six parts, of which the lower five-sixths form the plinths, and the upper sixth the mouldings.

BASIL, among carpenters and joiners, the iron side of the angle of a tool, ground so as to bring the end of the tool to a cutting edge. If the angle be very thin, the tool will cut more freely, but is in danger of breaking into notches, if not duly tempered: to remedy this, it is sometimes found necessary to grind it thicker.

BASILICA, (from *βασιλευς*, *king*, and *οικος*, *house*, signifying *royal house*,) a building originally used as a court of justice. Among the Romans, it was a large hall adjoining the forum, where the magistrates judged the people under cover, which distinguished it from the fora, where they held their sittings in the open air. Basilicas were in plan parallelogrammic, divided lengthwise into three or more aisles, the centre one of which was called the testudo, and those at the sides porticos. The testudo was covered by a roof supported on two rows of columns, situate on either side between it and the adjoining porticos. These porticos were divided vertically by two galleries, one above the other, which ran round three sides of the building, and were covered by a lean-to roof, meeting the above-named columns below their capitals, so as to leave an open space between the roofs of the porticos and the testudo, for the admission of light. At that end of the testudo where the gallery was discontinued, stood a raised platform, on which was placed the tribunal for the magistrate. The above is as clearly as can be discovered, a correct description of the ancient basilica, and agrees in all its principal features with a building which has been discovered in the ruins of Pompeii.

The proportions of these edifices are given by Vitruvius as follows:—"The breadth," he says, "is not to be less than a third, nor more than the half of the length, unless the nature of the place opposes the proportion, and obliges the symmetry to be different; but if the basilica has too much length, *chalcidicæ* (supposed to be apartments on the sides of the tribunal, separated from the body by a partition) are taken off the ends, as in the basilica of Julia Aquiliana. The columns of the basilica are made as high as the porticus is broad; which again is equal to the third part of the space in the middle. The upper columns are less than the lower, as above written. The *pluteum* (a kind of podium or continued pedestal) which is between the upper columns, should also be made a fourth part less than the same columns, that those who walk on the floor above, may not be seen by the negotiators below. The *epistylium*, *zophurus*, and *coronæ* below, are proportioned to the columns, as in my third book.

"Nor will basilicas such as that at the colony of Julia of Fanum, which I designed and executed, have less dignity and beauty, the proportions and symmetry of which are as follows: The middle testudo, between the columns, is one hundred and twenty feet long, and sixty feet broad. The porticus around the testudo, between the walls and columns, is twenty feet broad. The height of the continued columns, including their capitals, is fifty feet, and the thickness five, having behind them parastatæ (attached pilasters) twenty feet high, two feet and a half broad, and one foot and a half thick, which sustain the beams that bear the floors of the porticus. Above these are other parastatæ, eighteen feet high, two feet broad, and a foot thick, which also receive beams sustaining the canthers of the porticus, which are laid

below the roof of the testudo: the remaining space that is left between the beams which lie over the parastatæ, and those over the columns, is left open in the inter-columns, in order to give light. The columns in the breadth of the testudo, including those of the angles to the right and left, are four; and in the length, on that side which is next the forum, including the same angle columns, eight. On the other side, there are but six columns, including those of the angles, but the middle two on this side are omitted, that they may not obstruct the view of the pronaos of the Temple of Augustus, which is situated in the middle of the side-wall of the basilica, looking toward the centre of the forum and Temple of Jupiter. The tribunal, in this building, is formed in the figure of a hemicycle: the extent of this hemicycle, in front, is forty-six feet, and the recess of the curvature inward, fifteen feet, so that those who attend the magistrate obstruct not the negotiants in the basilica.

"Upon thecolumns, the compacted beams, made from three timbers of two feet, are disposed; and these are returned from the third columns, which are in the interior part, to the antæ that project from the pronaos, and on the right and left touch the hemicycle.

"Upon the beams, perpendicularly to the capitals, the pilæ (a kind of blocking for supporting the plates) are placed, three feet high, and four feet broad, on every side. Over these, other beams, well wrought from two timbers of two feet, are placed; upon which the transtraæ and capareols being fixed coincident with the zophorus, antæ, and walls of the pronaos, sustain the culmen the whole length of the basilica, and another transversely from the middle over the pronaos of the temple: so that it causes a double disposition of the fastigium, and gives a handsome appearance to the roof on the outside, and to the lofty testudo within. The omission of the ornaments of the epistylium, and of the upper columns and plutei, diminishes the labour of the work, and saves great part of the expense. The columns likewise being carried in one continued height up to the beams of the testudo, increase the magnificence and dignity of the work."

In the foregoing description, the proportion which Vitruvius assigns to basilicas in general, does not agree with that which he executed at the colony of Julia of Fanum, which appears to be of a different construction from the common form; as, in the former, the ranges of columns which form the porticos, appear to have been disposed in two heights, with a gallery between; whereas, in the latter, the columns were disposed in one range in the height, with attached pilasters behind, in two rows, one above the other, and the galleries between the pilasters nearly against the middle of the columns, resting upon the lower range. Nor are the proportions the same: for in the former, the breadth is specified not to be less than a third part of the length, nor more than half, "unless the nature of the place opposes the proportion;" the breadth of the latter is, however, more than the half, for the length of the nave is one hundred and twenty feet, and the breadth sixty feet; now, adding forty feet to each, the breadth of the two opposite porticos, will make the whole length of the building one hundred and sixty feet, and the breadth of the same one hundred feet, which is more than the half of one hundred and sixty. In the general construction, no columns are mentioned at the ends, unless the chalcidæ (which are introduced in order to proportionate the building) are comparted by columns, but in the basilica constructed by Vitruvius, porticos are clearly understood in the breadth, as well as in the length; for he says, "The columns in the breadth of the testudo, including those of the angles to the right and left, are four; and in the length, on that side which is next the forum, including the same columns, eight; on the other side there are but six columns, including those of the angles; because the middle two on this side are omitted, that they may not obstruct the view of the pronaos of the temple of Augustus." When Vitruvius speaks of the length and breadth of the basilica, it is reasonable to suppose, that these were the dimensions within the walls; but whether ancient edifices of this description had walls, or were supported upon columns, is a desideratum which cannot be ascertained, but in the discoveries of ancient edifices, which are perhaps, as yet, embosomed in the earth; and it is to be regretted, that, though some buildings of a similar description have been discovered, they are by no means decided, neither in their proportion nor construction. Fragments of the plan of Rome, taken under Severus, which still exists, show a part of the basilica Æmiliana, exhibiting two rows of columns on each side, without an exterior wall, which renders it doubtful whether they ever were enclosed or not; perhaps the warmth of the climate of Italy did not require it.

"It is to Constantine, that the first Christian churches, known by the name of basilicas, are to be referred. This prince signalized his zeal by the erection of monuments, which announced the triumph of the religion which he had embraced. He gave his own palace on the Cœlian mount, to construct on its site a church, which is recognized for the most ancient Christian basilica. A modern building has so masked and disfigured the ancient, that only the situation and plan of this monnment can be discovered.

"Soon after, he erected the basilica of St. Peter, of the Vatican. This magnificent edifice was constructed about the year 324, upon the site of the circus of Nero, and the temples of Apollo and Mars, which were destroyed for that purpose. It was divided internally into five aisles from east to west, which terminated at the end in another aisle from north to south, in the centre of which was a large niche or tribunal giving the whole the form of a cross. The larger aisle was enclosed by forty-eight columns of precious marble, and the lateral aisles had likewise forty-eight columns of smaller dimensions; two columns were placed on each wing of the terminating aisle. The whole was covered with a flat ceiling, composed of immense beams, which were cased with gilt metal and Corinthian brass, taken from the temples of Romulus and Jupiter Capitolinus. A hundred smaller columns ornamented the shrines and chapels. The walls were covered with paintings of religious subjects, and the tribunal was enriched with elaborate mosaics. An incredible number of lamps illuminated this temple; in the greater solemnities 2,400 were reckoned, of which one enormous candelabrum contained 1,360. The tombs of pontiffs, kings, cardinals, and princes, were reared against the walls, or insulated in the ample porticos.

"This superb temple was respected by Alaric and Totila, and remained uninjured in the various fortunes of Rome during the lapse of twelve centuries; but crumbling with age, it was at last pulled down by Julius II., and upon its site has arisen the famous basilica, the pride of modern Rome.

"The third great basilica built by Constantine, that of St. Paul, on the road to Ostia, still exists. The interior of this building resembles precisely that of St. Peter, which has just been described. Of the forty columns enclosing the great aisle, twenty-four are supposed to have been taken from the mausoleum of Adrian; they are Corinthian, about three feet diameter, fluted their whole length, and cabled to one-third: the columns are of blue-and-white marble, and antiquity presents nothing in this kind more precious for the materials and workmanship. But these beautiful remains

seem only to be placed there to the disgrace of the rest of the construction, which is of the age of Constantine and Theodosius, and which most strikingly exemplifies the rapid decline of the arts.

"The churches we have hitherto described, bear a very complete resemblance to the antique basilica in plan and proportion. The only remarkable difference is, that the superior galleries are suppressed, in the place of which a wall is raised upon the columns of the great aisle, which is pierced with windows, and supports the roof.

"The church of St. Agnes out of the walls, though not one of the seven churches of Rome which retain the title, is however a perfect imitation of the antique basilica. This resemblance is so complete, that without the testimony of writers, who inform us that it was built by Constantine, at the request of Constantia, his sister or daughter, and without the details of its architecture, which forbid us to date it higher, it might be taken rather for an ancient tribunal of justice, than a modern church. It forms an oblong internally, three sides of which are surrounded with columns forming the porticos; the fourth side opposite the entrance is recessed in a semicircle; this is the tribunal. The first order of columns carries a second, forming an upper gallery, above which begins the ceiling of the edifice. The shortening of the columns recommended by Vitruvius, is observed in the upper order.

"We have hitherto observed in the Christian basilicas, but small variations from the antique construction: they were still simple quadrilateral halls, divided into three or five aisles, the numerous columns of which supported the flat ceiling; but the cross-form, the emblem of Christianity, which began to be adopted in these buildings, operated the most essential changes in their shape. The intersection of the crossing aisles produced a centre, which it was natural to enlarge and make principal in the composition; and the invention of domes, supported on pendentives, enabled the architects to give size and dignity to the centre, without interrupting the vista of the aisles. The church of St. Sophia, at Constantinople, was the first example of this form.

"The seat of the Roman empire being transferred to Constantinople, it is natural to suppose that the disposition of the ancient St. Peter's of Rome, esteemed at that time the most magnificent church in the world, was imitated in that which Constantine erected for his new capital, under the name of St. Sophia. This last did not exist long: Constantius, the son of Constantine, raised a new one, which experienced many disasters. Destroyed in part, and rebuilt under the reign of Arcadius, it was burnt under Honorius, and re-established by Theodosius the younger; but a furious sedition having arisen under Justinian, it was reduced to ashes. This emperor having appeased the tumult, and wishing to immortalize his name by the edifice he was about to erect, assembledf rom various parts the most famous architects. Anthemius of Trulles, and Isidore of Miletus, were chosen; and as they had the boldness to attempt a novel construction, they experienced many difficulties and disasters; but at last they had the glory of finishing their design.

"The plan of this basilica is a square of about two hundred and fifty feet. The interior forms a Greek cross, that is, a cross with equal arms; the aisles are terminated at two ends by semicircles, and at the other two by square recesses, in which are placed two ranges of tribunals. The aisles are vaulted, and the centre, where they intersect, forms a long square, upon which is raised the dome, of about one hundred and ten feet diameter. The dome, therefore, is supported upon the four arches of the naves and the pendentives, or spandrel, which connect the square plan of the centre with the circle of the dome.

"The general effect of the interior is grand; but whatever praises the bold invention of this immense dome may merit, it must be confessed, that there are times in which princes, however great and liberal, can only produce imperfect monuments. of which this edifice is a striking example. All the details of its architecture are defective and barbarous.

"However, from the communication established between Greece and Italy, at the revival of letters, this basilica, the last, as well as the most magnificent of the lower empire, was that which influenced most the form and architecture of the new temples. The Venetians, in the tenth century, copied with success the best points in the disposition of St. Sophia, in the church of St. Mark. This is the first in Italy which was constructed with a dome supported on pendentives; and it is also this which first gave the idea, which has been imitated in St. Peter's, of the Vatican, of accompanying the great dome of a church with smaller and lower domes, to give it a pyramidal effect.

"From this time to the erection of the basilica of St. Peter's, we find the churches approach, more or less, to the form of the ancient basilica or the new construction. The church of Santa Maria del Fiore, of Florence, from the magnitude of its dome, and the skill which Brunelleschi displayed in its construction, acquired a celebrity which made the system of domes prevail; and this system was finally established in the noble basilica of the Vatican, which has become the type and example of later ones. The form of the antique basilica was entirely lost, and the name, which has been retained, is the only remain of their ancient resemblance.

"In the pontificate of Julius II., the beginning of the sixteenth century, the basilica of St. Peter's was begun from the designs of Bramante. This great man formed the idea of suspending, in the centre of the building, a circular temple, as large as the Pantheon, or, as he expressed it, to raise the Pantheon on the temple of peace; and, in fact, we find great resemblance in size and disposition between these two edifices and the project of Bramante. He was succeeded in his office by San Gallo, who almost entirely lost sight of the original plan; but Michael Angelo, to whom at his death the undertaking was committed, concentered the discordant parts. Michael Angelo died 1564, while he was engaged in erecting the dome; but he left plans and models, which were strictly adhered to by his successors, Vignola, J. del Porte, and Fontana, who terminated the dome. The building was carried on under many succeeding pontiffs; and at last, by lengthening the longitudinal nave, it acquired the form of the Latin cross; in that particular, approaching to the original design of Bramante.

"The general form of this edifice, externally, is an oblong, with circular projections in three of the sides; the plan of the interior consists of a Latin cross, the intersection of the arms of which is enlarged and formed into an octagon; the head of the long aisles, and the ends of the cross-aisles, are terminated in hemicycles, and the great naves are accompanied with lateral aisles, and with several enclosed chapels. The octagon centre supports a circular wall, enriched with pilasters and pierced with windows, above which rises the magnificent dome.

"Thus we have traced the progress of the basilica from the quadrilateral hall of the ancients, with its single roof and flat ceiling, supported on ranges of columns, to the cross-shaped plan, central dome, and vaulted aisles, supported on massy piers, of the modern cathedral. It only remains to treat of the—

"*Modern* BASILICA. We give this name, with Palladio, to the civil edifices which are found in many Italian cities, and the destination of which is entirely similar to the antique basilica.

"In imitation of the ancients, (says this celebrated architect,) the cities of Italy construct public halls, which may rightly be called *basilicas*, as they form part of the habitation of the supreme magistrate, and in them the judges administer justice. The basilicas of our time (he continues) differ in this from the ancient—that those were level with the ground, while ours are raised upon arches, in which are shops for various arts, and the merchandise of the city. There the prisons are also placed, and other buildings belonging to the public business. Another difference is, that the modern basilicas have the porticos on the outside, while in the ancient they were only in the interior. Of these halls, there is a very noble one at Padua; and another at Brescia, remarkable for its size and ornaments.

"But the most celebrated is that of Vicenza; the exterior part of which was built by Palladio, and the whole so much altered that it may pass for his work. The body of the building is of much greater antiquity, though the date of it is unknown.

"Time and various accidents had reduced this edifice to such a state of decay, that it was necessary to think seriously of preventing its total ruin: for this purpose, the most eminent architects were consulted, and the design of Palladio was approved. He removed the ancient loggias, and substituted new porticos, of a very beautiful invention. These form two galleries in height, the lower order of which is ornamented with Doric engaged columns, at very wide intervals, to answer to the internal pillars of the old building; the space between each column is occupied by an arch, resting on two small columns of the same order, and a pilaster at each side against the large columns, which leaves a space between it and the small columns, of two diameters. The upper portico of Ionic columns, is disposed in the same manner, and a balustrade is placed in the archways. The entablature of the large orders is profiled over each column.

"This edifice is about one hundred and fifty feet long, and sixty feet broad; the hall is raised above the ground twenty-six feet; it is formed by vaults supported on pillars, and the whole is covered with a wooden dome."—*Rees's Cyclopædia.*

BASKET, a kind of vase in the form of a basket, filled with flowers, or fruits, or both, used for terminating a decoration.

BASSE-COUR, a court separated from the principal one and destined for the stables, coach-horses, and livery-servants. In a country place, it denotes the yard where the cattle, fowls, &c., are kept: it is called by the French *menagerie.*

BASSO-RELIEVO, (*Italian;* Bas-relief, *French,*) in sculpture, is the representation of figures projecting from a back ground, so as to give relief. It is a general term, comprehending three distinct species of sculpture. Low relief, sometimes also called basso-relievo, is that in which no part of the sculpture is detached from the back ground: high-relief, or alto-relievo, is that in which the grosser parts are only attached, while the smaller parts are free: mean-relief, or mezzo-relievo, is a term which some use for a kind of sculpture between the two. Mezzo-relievo is distinguished from alto by having no part entirely disconnected from the plane surface, and from basso-relievo in having the parts most remote from the back ground, most relieved, whereas the latter has such parts least relieved. In the former the outline is less, in the latter more apparent than the forms within it.

These terms are of modern date, and probably invented in the eleventh and twelfth centuries. The Greeks denominated relievo, or low-relief, by the term *anaglypta* (Pliny, lib. 33, c. 11,) and alto-relievo was distinguished by the word *toreuticeu*, or rounded, (Pliny, lib. 34, c. 8,) although this term was occasionally applied to any kind of relief. As architecture is highly indebted to sculpture for some of its most elegant decorations, it will be proper to give some account in this place of the basso-relievos of the ancients.

In point of antiquity, the Egyptian stands first: a knowledge of their sculpture will be best obtained from the writings of those who have actually visited and surveyed their ruined edifices; in conformity with this, the following description from Denon will, perhaps, be acceptable:—"The hieroglyphics, which are executed in three different manners, are also of three species, and may take their date from as many periods. From the examination of the different edifices which have fallen under my eye, I imagine that the most ancient of these characters are only simple outlines, cut in without relief, and very deep; the next in point of age, and which produce the least effect, are simply in a very shallow relief; and the third, which seem to belong to a more improved age, and are executed at Tentyra more perfectly than in any other part of Egypt, are in relief below the level of the outline. By the side of the figures which compose these tabular pieces of sculpture, there are some hieroglyphics which appear to be only the explanation of the subjects at large, and in which the forms are more simplified, so as to give a more rapid inscription, or a kind of short-hand, if we may apply the term to sculpture.

"A fourth kind of hieroglyphics appears to be devoted simply to ornament: we have improperly termed it, I know not why, the *arabesque.* It was adopted by the Greeks, and, in the age of Augustus, was introduced among the Romans; and in the fifteenth century, during the restoration of the arts, it was transmitted by them to us, as a fantastic decoration, the peculiar taste of which formed all its merit. Among the Egyptians, who employed these ornaments with equal taste, every object had a meaning or moral, and at the same time formed the decoration of the friezes, cornices, and surbasements of their architecture. I have discovered at Tentyra the representations of the peristyles of temples in caryatides, which are executed in painting at the baths of Titus, and have been copied by Raphael, and which we constantly ape in our rooms, without suspecting that the Egyptians have given us the first models of them." Again, in describing the temple of Latopolis, Denon says, "The hieroglyphics in relief, with which it is covered within and without, are executed with great care; they contain, among other subjects, a zodiac, and large figures of men with crocodiles' heads: the capitals, though all different, have a very fine effect; and as an additional proof that the Egyptians borrowed nothing from other people, we may remark, that they have taken all the ornaments, of which those capitals are composed, from the productions of their own country, such as the lotus, the palm-tree, the vine, the rush, &c., &c." The most ancient and most simple kind of basso-relievos, used by the Egyptians, were cut by recessing the grounds as much as the projection of the figures, so that the surrounding surfaces, by forming a kind of border, both threw a shade upon the figures and defended them from injury, which they were liable to, as the granite out of which they were cut was of a very brittle nature; by this means much labour was saved in the execution.

The Egyptians also employed basso-relievo without any surrounding border, all the figures being raised from the same naked, such as in the palace of Karnac, and those

described in the Bird's Well, of which there is a specimen in the hall of the British Museum. The material is soft calcareous stone, in very low relief. The outlines of Egyptian sculpture are ungraceful, and the execution shows a want of the knowledge of anatomy: it may be remarked as somewhat singular, that quadrupeds are more accurately represented in their sculpture than human figures.

The basso-relievos found in the excavations of the Indian temples bear a strong resemblance to those of the Egyptians, but are inferior in point of proportion; the heads are too large. Whether the Indian or Egyptian sculpture is the most ancient is not known; but if simplicity is to be our criterion, we would say the latter. See *Daniell's Ant.*

The Persians employed basso-relievos in their architectural decorations, as may be seen in the palace of Persepolis, and in the royal tombs. The figures are arranged in horizontal and vertical lines, and resemble the later hieroglyphics of Egypt, though the dress is very different: those of the Egyptians being particularly distinguished by the hair artificially curled, the hood, the mitre, the close tunic, and apron of papyrus; the Hindoos, by the necklaces, bracelets, and anklets; the Persians, by long beards, and hair ending in small curls, caps, and full tunics, with regular folds and large sleeves; the Medes, by close tunics. The drapery of the Persian figures is more natural than that of the Egyptians; but it cannot be inferred from this, that the figures themselves are of better sculpture, as instances may be shown to the contrary, in the obelisk of Sesostris, in the palace of Karnac, and in the Theban tombs, where the execution is not only more perfect, but the positions of the human figures more varied. See *Denon's Egypt*, and *Le Bruyn's Travels.*

The Grecians excelled all contemporary nations in the art of sculpture, as well as in architecture and geometry; the numerous remains of their edifices show the perfection which they had attained in exquisite workmanship, beautiful proportion, and easy and graceful attitudes. They profess to have had their first rudiments from Egypt, and this is completely verified in their first productions, which were similar to those of the Egyptians; however, the art did not long remain stationary; from daily observation, and a strict adherence to nature, they advanced rapidly in the science, and at last, by a knowledge of anatomy, it was brought to such a degree of perfection, that their remaining sculptures have become the very standard of excellence, a criterion which the moderns have never surpassed, and but seldom equalled. Who can behold the sculpture in the pediments and friezes of the Parthenon, and other remains of Athenian grandeur, without astonishment?

The pediments of this temple were adorned with entire and separate statues, although from their situation, and the deep shadows cast by them on the tympanum, they must have had the appearance of figures in high relief. The figures in the metopes were in alto, whilst those in the cella were in basso-relievo. This arrangement leads us to notice the great judgment which the Greeks exercised in the selection of the different kinds of sculpture, according to the nature of the situation they were intended to occupy. We find that they almost invariably placed separate statues, and sculptures in high relief, on the exterior of their buildings, or in such places as had the advantage of the open light; while, on the contrary, they reserved those in basso-relievo for interiors, where the light was not freely admitted; and this they did evidently for this reason, viz. that in all situations, and under all circumstances, their sculptures might be distinct and intelligible. It needs no argument to prove that figures in high relief are more readily discernible, when the light is permitted to play equally on all sides of them. Were such figures placed in an imperfectly lighted situation, they would be almost unintelligible, from the shadows which they would throw upon each other. On the other hand, the flatness of basso-relievo, while it obviated the projection of shadows beyond its own surface, ensured the distinctness of the outlines, and gave to the figures an appearance of rotundity. Mezzo-relievo is only adapted for near inspection. The temples of Theseus and Phigaleia, as well as that of Minerva, were remarkable for the beauty of their sculptures.

The basso-relievos of the Romans were, perhaps, at first, confined to their tombs. They never attained a just knowledge, or taste, of the art of sculpture. Their best works were executed by Grecian artists, and are chiefly to be found in the triumphal arches, which are richly charged with basso-relievos. The art attained its greatest perfection in the reign of Augustus, and was greatly on the decline in the time of Constantine. In more modern times, the Italians and Florentines are the only people who arrived at any degree of excellence in sculptures of this kind; and even they departed from the original purity of the Greeks, by attempting to express in their works the effect of perspective. We are indebted to Flaxman for the introduction of a purer taste into this country; his style may be considered as a nearer approach to the simplicity of the ancients, than that of either the Italians or the Florentines.

BASTION, or BATOON. *See* TORUS.

BAT, a part of a brick.

BATH, a house with accommodation for bathing. The ancient baths at Rome were very spacious and magnificent structures, and contained hot and cold baths, gymnasia, ambulatories, and even libraries. The most remarkable are those of Agrippa, Titus, Diocletian, and Caracalla.

The practice of bathing having been more generally adopted in this country within the last few years, has caused various structures to be erected for the purpose. These, however, are but of small dimensions, and have little pretensions to architectural embellishment.

BATTEN, a scantling of stuff, from two to six inches broad, and from five-eighths to two inches thick. Battens are employed in the boarding of floors, and also upon walls, in order to secure the laths on which the plaster is laid.

BATTEN-DOOR. *See* DOOR.

BATTEN-FLOOR. *See* BOARDED-FLOORS.

BATTENING, the act of fixing battens to walls, in order to secure the laths over which the plaster is laid; or, the battens in the state of being fixed for that purpose. The battens employed are generally about two inches broad, and three-fourths of an inch thick; they may, however, be of various thicknesses, according to the distances the several fixed points in their length are from each other. Their distance in the clear is from eleven inches to one foot. Previous to the fixing of battens, either equidistant bond-timbers should be built in the wall, or the wall should be plugged equidistantly, and the plugs cut off flush with its surface. In London, plugs are generally placed at the distance of one foot or fourteen inches from centre to centre in the length of the batten. Battens upon exterior walls, quarters in partition walls, the ceiling and bridging joists of a naked floor, also the common joists for supporting the boarding of a floor, are fixed at the same distance, viz. from eleven to twelve inches in the clear. When battens are fixed against flues, iron holdfasts are necessarily employed instead of bond-timbers or plugs. When battens are attached to a wall, they are generally fixed in vertical lines; and when fixed to the surface of a brick or stone vault, the intrados of which may be generated by a plane revolving about an axis, they ought to be placed in planes tending to the axis;

as, in this position, they have only to be fixed in straight lines, in cases where the intrados is straight towards the axis: such cases occur when the vault is a portion of a cone or cylinder. When the intrados is curved towards the axis, the battens will bend very readily. Great care should be taken to regulate the faces of the battens, so as to be as nearly equidistant as possible from the intended surface of the plaster. Though battens are employed in floors, neither the act of laying them, nor the floor formed of them afterwards, is called *battening;* they are more commonly called *boarding.* Every piece of masonry or brick-work, which is not sufficiently dry, should be battened for lath and plaster; particularly that which is executed in a wet season. When the windows are boarded, and the walls of a room not sufficiently thick to contain the shutters, the surface of the plastering is brought out so as to give the architrave a proper projection, and quarterings are used for supporting the lath and plaster, instead of battens. The like practice is observed, when the breast of a chimney projects into the room, in order to cover the recesses, and make the whole side flush, or in the same surface with the breast.

BATTER, the declension of a wall from the perpendicular: if a plummet be freely suspended from any part of a wall by a plumb-rule, the line coinciding with the draught, and the bottom part of the rule only touching the wall, then the wall is said to batter. This property applies both to straight and circular walls. A wall may be made to batter in any degree, by using a battering-rule, instead of a plumb-rule; that is, a rule which has the plummet draught oblique to the edge of the rule which is to be applied to the wall. This obliquity is best calculated by the rule of proportion, *viz.* if the whole height of the building batters at a given distance, what will a given length of rule batter? This distance being found, the top of the rule must be so much broader than the bottom, that is, reckoning from the draught to the edge applied to the wall, for the direction of the other edge is of no consequence. Upon this principle, even a body with a curved vertical section may be built; but in this case the rule will not shift; if the building stands on a circular plan, it can only be applied at the same altitude all round; and to carry the building to the summit, a new rule must be made at convenient portions of each successive altitude.

BATTLED-EMBATTLED, is when the top of a wall has a double row of battlements, formed of a conjunction of straight lines at right angles to each other, both embrasures and rising parts being double; the lower part of each embrasure less than the upper, and consequently the lower part of each riser broader than the upper.

BATTLEMENTS, indentations on the top of a wall, parapet, or other building. They were first used in ancient fortifications, and were afterwards applied to churches and other buildings, as mere ornaments. Their outline is generally a conjunction of straight lines at right angles to each other; each indentation having two interior right angles, and each raised part two exterior right angles. Sometimes the horizontal section of the rising part is a rectangle, while the bottom of the battlement, and top of the projecting part, slope downward, so as to form an obtuse angle with the face of the wall; occasionally, however, the plans of the upright sides of the battlements form the same obtuse angle as the bottom and top of the rising part. At other times both vertical and horizontal sections are right angles, ornamented equally all round with mouldings, or with a small square projecture: when the vertical sides of the embrasures are perpendicular to the face, the sloping cope generally terminates with a torus or large astragal. In process of time battlements were not confined to crown the principal walls of the building; but were employed in the finish of subordinate parts: they are to be found in the decorations of the transoms of windows, as in those of King Henry the Seventh's chapel, at Westminster. In this, and in every other case, they are proportioned to the architecture they accompany. The battlements employed in the florid style, were perforated in a most beautiful manner, with openings variously formed in symmetrical figures: such are the latticed battlements, and those formed of polyfoils, &c. The battlements used in this style of building, have not always their parts at right angles to each other, but frequently the standing parts, or those which form the sides of the openings, are raised in the manner of a pediment.

BAULK, a piece of timber, from four to ten inches square.

BAULK-ROOFING, is when the framing is constructed of baulk-timber.

BAY, the open space in a window included between the mullions, otherwise called a *day* or *light.* Also the quadrangular space between the principal ribs of a groined roof, across which the diagonal ribs are extended; or the spaces between the principal divisions of a timber roof. The term is also applied to that part of a building situated between two buttresses.

BAY OF A BARN, that part situate between the threshing floor and the end of the building, used for depositing the refuse hay or the corn previous to threshing.

BAY OF JOISTS, the joisting between two binding joists, or between two girders, when there are no binding joists.

BAY WINDOW, a projecting window of a polygonal plan, and rising from the ground or the basement of the building. *See* BOW AND ORIEL WINDOWS.

BAZAR, or BAZAAR, among the Turks and Persians, an exchange, where the finest stuffs and wares are sold. Some are open like market-places, others are covered with lofty ceilings, with pierced domes to give light. In these, jewellers, goldsmiths, and other dealers in the richest wares, have their shops.

BEAD, in joinery, a moulding of a circular section, stuck on the edge of a piece of stuff, by a plane of the same name. Beads are of two kinds, one of which is flush with the surface, and the other raised: the former is called a *quirk-bead,* and the latter a *cock-bead.*

BEAD AND BUTT WORK, in joinery, a piece of framing having the panels flush with the framing, and stuck or run upon the two edges, which have the grain of the wood in their direction.

BEAD and QUIRK, is when a bead is stuck on the edge of a piece of stuff, flush with the surface, with one quirk only, or without being returned on the other surface.

BEAD and DOUBLE QUIRK. *See* RETURN BEAD.

BEAD and FLUSH WORK, in joinery, a piece of framed work, having a bead run upon every edge of the framing which adjoins to each edge of the included panel.

BEAD, BUTT, and SQUARE WORK, a piece of framing, having bead and butt upon one side, and square on the other. Bead, butt, and square work is chiefly used in doors.

BEAD, FLUSH, and SQUARE, a piece of framing, having bead and flush on one side, and nothing but square work on the other; chiefly used in doors.

BEAK, a little pendent fillet, left on the edge of the larmier, which forms a canal behind, for preventing the water from running down the lower bed of the cornice. Sometimes the beak is formed by a channel or groove, recessed on the soffit of the larmier upwards. In the Ionic temple on the Ilyssus, at Athens, the canal occupies the whole breadth of the soffit, and so deeply recessed, that the

lower bed of the cornice is wrought almost out of the height of the recess.

Beak-head Moulding, a moulding used very commonly in Norman architecture, consisting of ornaments of a peculiar character, placed at regular intervals on a simple moulding. The ornaments may be described as grotesque heads, some apparently of animals, and some approaching the human form, but all invariably terminating in a pointed mouth, or beak as it were, whence their name. Although such ornaments were very frequent, they were of very various designs, two similar ones being seldom found in the same moulding.

Beaking Joint, in carpentry, is when the heading joints of the boards of a floor fall in the same straight line. This word is not used in London.

BEAM, when used in a building, is a piece of timber, or sometimes of metal, for sustaining a weight, or counteracting two equal and opposite forces, either drawing or compressing it to the direction of its length: when it is employed as a lintel, it supports a weight; when as a tie-beam, it is drawn or extended; and when as a collar-beam, it is compressed. The word *beam* is most frequently subjoined to another word, used adjectively, or in apposition, which shows the use, situation, or form of the beam: as tie-beam, collar-beam, dragon-beam, straining-beam, camber-beam, hammer-beam, binding-beam, girding-beam, truss-beam, summer-beam, &c. Some of these are also used simply, as, collar, instead of collar-beam; lintel, instead of lintel-beam; girder, instead of girding-beam; summer, instead of summer-beam. Lintels and girders are almost constantly used alone, and bressummers and joists are never used in composition. What is here called *collar-beam*, is, in old writers, termed *wind-beam*, *strut-beam*, or *strutting-beam*.

A beam is either lengthened by building it in thicknesses. or by lapping or splicing the ends upon each other, and bolting them through. *See* Building of Beams and Scarfing. For the manner of strengthening beams, see Truss-Beams.

Beam-Compass, an instrument, consisting of wood or metal, with sliding sockets, carrying steel or pencil points, used for describing large circles, beyond the reach of common compasses.

Beam-filling, the building of masonry, or brick-work, from the level of the under edges of the beams, to that of their upper edges. Beam-filling occurs either between joists, or floor-beams, or in filling up the triangular space between the top of the wall-plate of the roof, and the lower edges of the rafters, or even to the under surface of the boarding or lath, for slates, tiles, or thatching. This operation is necessary in garret-rooms, where the walls form sides of apartments; where the tie-beams are placed above the bottom of the rafters, and where the sides of the apartments are not to be battened and lathed for plaster, in order to straight the walls. Even in all other cases it is preferable, for the sake of comfort, to beam-fill the spaces.

BEARER, a prop, or anything that supports a body in any place; as a wall, post, strut, &c. In guttering, bearers are short pieces of timber for supporting the boarding.

Bearing of a Piece of Timber, the unsupported distance between the two points or props from which it is suspended; or the distance between two props where there is no intervening support.

A piece of timber, having any number of supports, one being placed at each extreme, will have as many bearings, wanting one, as there are supports: thus, a piece of timber extended in length over two rooms as joists. will have three supports and two bearings: here the bearers are the two most distant walls and the partition.

Bearing, at the ends of a piece of timber, in building is the distance which the ends of that piece are inserted in the walls or piers; as joists are inserted at least nine inches in walls, and the lintel or lintels of an aperture, nine inches at least into each pier.

Bearing Wall, or Partition, in a building, is a wall which rests upon the solid, and which supports some part of the building, as another wall or partition, either transversely, or in the same direction. When the supporting wall, and the wall supported, are both in the same direction, the wall supported is said to have a *solid bearing;* but if a wall, or partition, is not supported below throughout its length, it is said to have a *false bearing*, or as many false bearings as there are intervals below the wall or partition.

BEATER, an implement in plastering, used by the labourers, for tempering or incorporating the lime, sand, and hair together; which make the composition called lime and hair, used in first and second coatings, and sometimes, in ordinary rooms, even for finishing coats.

BED-CHAMBERS, or Bed-Rooms, are those in which beds are placed; when very small, they are called bed-closets.

Beds of a Stone, the two surfaces which generally intersect the face of the work in horizontal lines, or in lines nearly so: the higher surface is called the *upper-bed*, and the lower the *under-bed*. In the general run of walling, they are the two surfaces which are placed level in the building. In the parapets of bridges they intersect the facing, most frequently in lines parallel to the road-way, but are level in the thickness. In every species of vaulting, where all the sections of the intrados of a vault are similar figures, or parallel straight lines, the beds are those surfaces which intersect the intrados in horizontal lines. Of this class are the heads of circular domes, which have spherical or spheroidal intradosses; vaults with conic intradosses, and vertical axes; and vaults with cylindrical intradosses and horizontal axes, &c.

Beds of a Stone, in cylindrical vaulting, are those two surfaces which intersect the intrados of the vault, in lines parallel to the axis of the cylinder.

Beds of a Stone, in conic vaulting with a horizontal axis, are those two surfaces which, if produced, would intersect the axis of the cone. The beds of stones, in spherical vaulting, are, or should be, parts of the surfaces of so many cones, ending in a common vertex, as there are courses of stone. If the vault be a hemisphere, the under beds of all the stones in the lowest course or planes, and the upper beds, form part of the surface of a very obtuse-angled cone. In every course of stones, the conic surface formed by the lower beds is that of a cone, with a more obtuse angle than the surface formed by the upper beds of the same course; hence the cones of every successive joint upwards, have their vertical angles continually less, so as to end at last with the axis itself. In vaulting with a conic intrados and vertical axis, the joints form the surfaces of so many distinct cones, which have their vertex in the axis, and which have equal vertical angles, and their surfaces equidistant. In cylindrical, or conic vaulting, with a horizontal axis, the beds of the stones are in planes tending to the axis.

In arching, the beds are called *summerings;* but more properly, *radiations*, or *radiated joints*.

Bed of a Slate, the lower side placed in contiguity with the boarding or the rafters.

Bed Moulding, that portion of a cornice which is situated immediately below the corona.

BEETLE, a large mallet for driving piles, and cleaving wood.

BELECTION MOULDINGS, in joinery, are those which surround the panels, and project without the surface of the framing in doors, or other panelled framing. Belection mouldings are never stuck on the framing, which is frequently the case with those which are within or below the surface. They are used in the best work of grand finishings.

BELFRY, that part of a steeple wherein the bells are hung. This is sometimes called, by writers of the middle age, *campanile*. Bells are generally suspended by means of frame-work, which is supported on stone corbels; sometimes however, the framing is made to bear on a recess formed in the wall, which is the better method, as the vibration caused by ringing has less power to disturb the masonry. Bells for the same reason should be hung as low as practicable.

BELFRY, is more particularly applied to the timber-work, by which the bells are supported.

BELL, of the Corinthian and Composite capitals, is the vase or tambour concealed beneath the acanthus leaves, or other ornament: its horizontal section is everywhere a circle; the bottom part rises vertically from the top of the shaft, and proceeds upwards in a straight line to a considerable distance; from thence it changes into a concavity, which terminates with the fillet, in the manner of the scape or apophyge.

BELL-COT, BELL-GABLE, or BELL-TURRET. A small open turret situate on the apex of the gable of small Gothic churches, generally at the east or west end of the nave, for the purpose of sustaining one or two bells. It is sometimes of an hexagonal or multangular plan, covered with a pyramidal roof, or spire, of which kind there is a beautiful specimen at Corston Church, Wiltshire; it most generally, however, consists of a continuation of a certain width of the gable wall to a considerable height above the apex, the part above which is perforated with one or more arched apertures in which the bells are hung; above this again the roof is finished in the form of a gable, and the whole is surmounted by a finial or cross. Examples of such gables frequently occur; we may instance an elegant one at Skelton, near York. Plain timber bell-cots of square plan and low pyramidal roof, are very common in Essex.

Bell-gables at the eastern extremity of the nave were generally appropriated to the sanctus or sacringe bells, which was rung when the priest pronounced the Ter-sanctus, as also at the elevation of the host.

BELL-ROOF, that of which the vertical section perpendicular to the wall, or to its springing line, is a curve of contrary flexure; it being concave at the bottom, and convex at the top. A bell-roof is of that kind of ogee-roofs, called the *sima recta roof.*

BELT, in masonry, a course of stones projecting from the naked, either moulded, plain, fluted, or enriched with pateras at regular intervals, which again may be either plain or fluted.

BELVEDERE, or LOOK-OUT, is a turret, or some part of an edifice raised above the roof, for the purpose of affording a view of surrounding scenery. This term is also applied to single edifices or temples, sometimes erected in gardens and pleasure-grounds, used for the above purpose, as well as to beautify the landscape. Belvederes are very common in Italy and France, and some of them are very magnificent: the most celebrated is that built by Bramante in the Vatican.

BENCH, the table on which joinery for the use of building is prepared. *See* JOINERY.

BENCH-HOOK, a movable pin, passing through a mortise in the top of the bench, for preventing the stuff wrought by the plane from sliding.

BEND. *See* BENDING.

BENDA. *See* FASCIA.

BENDING, the act of the incurvation of a body from a straight to a crooked form. A piece of timber, such as a plank, may be very conveniently bent, by placing it within a long hollow prismatic trunk, opened only at one end for its insertion; the end through which it is introduced is then shut close, and the one extremity of a steam-pipe having been inserted in a hole in one of the sides or ends of the trunk, all the crevices are shut, and the steam is admitted.

When the plank has remained for a certain time, it may be taken out, and should be immediately bent round the convex surface of an inflexible body, made on purpose; when it has been properly fixed to the body, it is to remain till it is quite cold, or properly stiff, and it will retain its form: after this, it may be taken off and dressed, and lastly fixed in its intended situation. The practice of ship-building proves that plank-wood, of almost any thickness, may be brought to any degree of curvature, by the effect of heat, which seems to mollify the cementing matter, so as to permit the fibres to slide overone another. This may be effected either by boiling or heating; but by heating, it is very difficult to introduce a uniform temperature throughout the parts of the body to be bent. For thick planks a sand-stove, similar to the sand bath used in chemical operations, is employed; but for thin planks, a vapour-stove.

BERNINI, GIOVANNI LORENZO, born 1598, died 1680. His father, Pietro Bernini, a Florentine, was a painter and sculptor of more than common talents. Giovanni's first work in architecture was the great central altar of St. Peter's, remarkable for its twisted columns; its novelty, singularity, and the difficulty of its execution surprised, and had many imitators. By desire of the pope, he adorned with niches the four great piers which support the cupola of St. Peter's. He was employed in the construction of the palace Barberini, particularly in that of the stairs, the great hall, and the principal front. The front has on the lower floor a Doric, very well understood; but the application of so many cornices, and the great arched windows, do not add to the beauty of the structure. The front of the Propaganda Fide is also the work of Bernini: that building threatened ruin, to prevent which he erected a battering basement, which increased at the same time both the beauty and strength of the structure. Urban VIII. wishing to complete the front of St. Peter's, which, according to the design of Maderno, required, at its extremities, two steeples, gave the commission to Bernini. He designed and executed the fine fountain of the Piazza Navona. For Prince Ludovisi, he begun a great palace, which in its principal front presented five faces; this edifice was afterwards converted into a great law-court, called *Curia Innocenziana*, one of the finest palaces in Rome. Alexander VII. gave him many works to execute, among which is the piazza before St. Peter's. By order of this pope, he planned many buildings, among which is remarkable, the palace of Santi Apostoli. The very elegant church, of an elliptic figure, of the Novitiate of the Jesuits, is likewise his. Louis XIV. and Colbert his minister, both admirers of the fine arts, ordered Bernini to make drawings for the palace of the Louvre, for which building the first architects were stimulated; these drawings pleased so much, that the monarch sent him his portrait set in gems, and wrote very engaging letters to the pope, and to Bernini himself, that he might go to France to execute them. In consequence of which, though an old man, he left Rome, and went to Paris, where he was received as if the only man worthy to work for Louis XIV. When Bernini had seen the front of the Louvre, by Perault, he said publicly, that his coming to France was useless, where there were architects of the first

class. This trait does more honour to Bernini, than all his abilities as an architect. In fact, with regard to architecture, which he was sent principally for to France, he did nothing. He made the king's bust, and during the eight months he staid in France, he was paid at the rate of five pounds a day; and received at last a gift of 50,000 crowns, and an annual pension of 2000, and a pension for his son, whom he took with him, of 500. When he returned to France, in gratitude to his majesty, he made an equestrian statue, which was placed in Versailles. Under Pope Clement IX. he embellished the bridge of St. Angelo with an elegant iron balustrade.

BEVEL, the oblique angle which the two surfaces of a body make with one another; the name also of an instrument for taking oblique angles. That which is most commonly used, has the stock mortised to receive the blade, which is fixed to the stock by a pin, and made to form any angle by that means: this is particularly useful when one or a few angles are to be taken. In some places, for the want of space, this bevel cannot be applied: to accommodate this circumstance, the blade is made to shift in the stock; so that either part from the pin may be of any given length. The blade is made to pass through the pin by a longitudinal mortise, and fixed fast to the stock by means of a screw, after setting it to the angle When many things are to be wrought to the same angle, an immovable bevel should be used, particularly when the blade, or stock, or both, are incurvated: when the interior angle is used, this bevel is called a *joint-hook*. In working the intradosses, and radiating beds of stone arches, a joint-hook should be employed; one of the sides is incurvated to the arch, and the other straight side is a part of the radius produced: the workman must here observe, that this hook will apply, whatever be the thickness of the stones.

BILLET MOULDING, a moulding peculiar to Norman architecture, consisting of small cylinders placed lengthwise at regular distances in a concave semicircular moulding. The entire moulding consisted generally of two rows or tiers; the cylinders in each tier ranged in such a manner that one cylinder should not come immediately above or below another, but they were placed alternately so that a space was always opposed to a cylinder, and *vice versâ*. A square billet, called also corbel-bole, is likewise found. This differs from the above, inasmuch as the billets are cubes instead of cylinders, and are placed on a flat band, or on the naked walling, their usual office being to support a blocking course.

BINDING JOISTS, those beams in a floor, which support transversely the bridgings above, and the ceiling joists below. *See* Bridging Floors.

When binding joists are placed parallel to the chimney-side of a room, the extreme one on this side ought never to be placed close to the breast, but at a distance equal to the breadth of the slab, in order to allow for the throwing of the brick trimmer for the support of the hearth.

Binding-Rafters, the same as Purlins.

BIRD'S-MOUTH, an interior angle cut on the end of a piece of timber, in order to rest firmly upon an exterior angle of another piece.

BIT, a boring instrument, so constructed as to be inserted or taken out of a handle, called a *stock*, by means of a spring. The general form of the handle is divided into five parts, all in the same plane, the middle and two extreme parts being parallel. The two extreme parts are in the same straight line, one of them has a brass end, with a socket for containing the bit, which when fixed falls into the same straight line with the other end of the stock; the farther end has a knob so attached as to remain stationary; while all the other parts of the apparatus may be turned round by means of the projecting part of the handle.

Bits are of various kinds, depending on their use:

Shell Bits are used for boring wood, and have an interior cylindric concavity for containing the core.

Centre Bits, are those which run upon a centre in the middle of the breadth; one extremity is formed into a cutting edge, which cuts the wood across the grain around the circumference, and the radius on the other side of the centre contains a cutting edge, the whole length of this radius, and projects forward from the face of the bit, so as to take out the core, which in the act of boring forms a spiral.

The use of the centre-bit, is to form a large cylindric hole or excavation, having the upper point of the axis of the cylinder given on the surface of the wood. The centre of the bit is fixed into this point, then placing the axis of the stock and bit in the intended direction, the head being placed against the breast, turn it swiftly round by the handle, and the core will be discharged by rising upwards. Centre bits are of different diameters.

Countersinks, are bits for widening the upper part of a hole, in wood or iron, to take in the head of a screw or pin, so as not to appear above the surface of the wood. Countersinks have from two to twelve cutters around the surface of a cone, which contains a vertical angle of ninety degrees. Countersinks for iron have two cutting edges, and those for wood and brass, the greatest number.

Rimers, are bits for widening holes, and for this purpose are of a pyramidal structure, having their vertical angle about $3\frac{1}{2}$ degrees. In the use of rimers, the hole must be first pierced by means of a drill or punch. The operation of a rimer is rather scraping than boring. Rimers for boring brass, have their horizontal sections of a semicircular figure, and those for iron, polygonal.

Taper Shell Bits, are conical within and without, with their horizontal sections crescent-formed. The use of shell-bits is to widen holes in wood.

Besides the above bits, some stocks are provided with a screwdriver, for sinking small screws into wood with greater rapidity that could be done by hand.

BITUMEN, a tenacious matter, used in early Eastern structures, instead of mortar. The walls of Babylon, we are informed, were cemented with this matter. *See* Asphaltum.

BLANK Door, is that which is either shut to prevent passage, or placed in the back of a recess, where there is no entrance, so as to appear like a real door.

Blank Window, is that which is made to appear like a real window; but is only formed in the recess of a wall. When it is necessary to introduce blank windows, in order to preserve the symmetry, it is much better to build the apertures as the other real windows, provided that flues or funnels does not interfere, and instead of representing the sashes with paint, real sashes should be introduced: the panes of glass may be painted on the back.

BLINDS, screens forming an appendage to a window, for the purpose either of excluding light, or of preventing persons outside from seeing into the interior of an apartment. Blinds are made of various materials, and of forms too numerous and too well known to need description in this work.

BLOCKING-COURSE, or simply Blocking, in masonry, a course of stones laid on the top of the cornice, crowning the walls. The blocking-courses were used by the ancients to terminate the walls of a building, as well as attics. The pilastrade of the arch of the Goldsmiths, at Rome, is surrounded with a blocking-course, the height of which is nearly equal to the breadth of the pilasters. The height of that on the Colosseum is nearly once and a half of the pilasters, or nearly equal to the cornice and frieze taken together: the same may be said of the amphitheatre at

Verona. The blocking-course of the temple of Jupiter, at Spalatro, is in height something less that the upper diameter of the column.

Blockings, in joinery, are small pieces of timber fitted in, and glued or fixed to the interior angle of two boards, or other pieces, in order to give additional strength to the joint. In gluing up columns, the staves are all successively glued, and strengthened with blockings; also the risers and treads of stairs, and all other joinings that require more additional strength than what their own joints will give. Blockings are always concealed from the sight.

BLONDEL, John Francis, died 1773, at Metz. He constructed the royal abbey of St. Louis, with a square and street, leading directly opposite to the cathedral; he erected also the town-house, with a building opposite, and farther on barracks, with magazines over them. The fine front of the parliament-house, and the sumptuous palace of the bishop, are also his works. He showed no less ability at Strasburg, where, in 1768, he took the plan of that city, and built there barracks for infantry and cavalry, a hall or amphitheatre, with three tiers of boxes, a royal square, a senate-house, a market, and various stone bridges. This celebrated architect, besides other works executed at Paris and elsewhere, furnished the plates of the last edition of D'Avilen on French architecture, in three volumes, with six hundred plates of the principal edifices in France. These three volumes were to have been followed by five others. He established an architectural school at Paris, in 1744. In the middle of all this work, he became a writer for the French Encyclopedia; but his great work, of universal utility, is the *Course of Architecture*, the result, as he says, of forty years' experience and researches. The work is divided into three parts; the first regards beauty or decoration, and is comprised in two volumes in octavo, with the volume of figures; the second treats of convenience or distribution, and contains the like number of volumes; the third part, on the solidity of building, the author did not live to complete.

BOARD, a piece of timber, of an oblong or trapezoidal section, and of any length. All timbers less than two inches and a half in thickness, and more than four inches broad, may be called boards.

When boards are of a trapezoidal section, that is, thinner on one edge than the other, they are called *feather-edged boards.* Boards broader than nine inches, are called *planks.* Fir boards are called *deals;* these are generally imported into England ready sawed, because they are prepared cheaper abroad, by means of saw-mills. Fir boards, one inch and a quarter thick, are called *whole-deal;* and those full half an inch thick, are called *slit-deal.*

BOARDED FLOORS, are those covered with boards. The operation of boarding floors may commence as soon as the windows are in, and the plaster dry. The preparations of the boards for this purpose are as follow. They should be planed on their best face, and set out to season till the natural sap has been quite expelled. *See* Seasoning of Wood. They may next be planed smooth, shot and squared upon one edge; the opposite edges are brought to a breadth, by drawing a line on the face parallel to the other edge with a flooring guage; they are then guaged to a thickness with a common guage, and rebated down on the back to the lines drawn by the guage. The next thing to be done is to try the joists, whether they be level or not; if they are found to be depressed in the middle, they must be furred up; and if found to be protuberant, must be reduced by the adze: the former is more generally the case. The boards employed in flooring are either battens, or deals of greater breadth. With reference to quality, battens are divided into three classes; the best kind is that free from knots, shakes, sapwood, or cross-grained stuff, and well matched, that is, selected with the greatest care; the second best is that in which only small but sound knots are permitted, and free from shakes and sapwood; the most common kind is that which is left after taking away the best and second-best.

With regard to the joints of flooring-boards, they are either quite square, plowed and tongued, rebated, or doweled: in fixing them they are nailed either upon one or both edges. They are always necessarily nailed on both edges when the joints are plain or square, without dowels. When they are doweled, they may be nailed on one or both edges; but in the best doweled work, the outer edge only is nailed, by driving the brad obliquely through that edge, without piercing the surface of the boards, so that the surface of the floor, when cleaned off, appears without blemish. In laying boarded floors, the boards are sometimes laid after one another; or otherwise, one is first laid, then another, leaving an interval something less than the breadth of three, four, or five boards in contact; so that if the first and sixth boards are laid, there will be an interval something less than the breadth of four boards. Now place the four intermediate boards in contact with each other, and the two outer edges in contact with the edges of the first and sixth boards already laid. The space left, as above mentioned, being somewhat less than the width of four boards, will not allow this number to lie flat, but will cause them to assume the form of an arch, having the under parts of the edges in close contact, while the upper parts will remain open. In order, therefore, to bring them to a level and the joints close, two or more workmen must jump upon the ridges till they have brought the under sides of the boards close to the joists, when they are fixed in their places with brads. In this last method the boards are said to be folded. This mode is only adopted when the boards are not sufficiently seasoned, or suspected to be so. In order to make close work, it is obvious that the two edges, forming each of the three joists of the second and third, third and fourth, fourth and fifth boards, must form angles with the faces, each less than a right angle. The eleventh board is fixed as the sixth, and the seventh, eighth, ninth, and tenth, are inserted as the second, third, fourth, and fifth; and so on till the completion. The headings are either square, splayed, or plowed and tongued. When it is necessary to have a heading in the length of the floor, it should always be upon a joist, and one heading should never meet another. When floors are doweled, it is more necessary to place dowels over the middle of the inter-joist than over the joists, in order to prevent the edge of the one board from passing that of the other. When the boards are only bradded upon one edge, the brads are most frequently concealed, by driving flooring-brads slantingly through the outer edge of every successive board without piercing the upper surface.

In adzing away the under-sides of the boards opposite to the joists in order to equalize their thickness, the greatest care should be taken to chip them straight, and exactly down to the rebates, as the soundness of the floor depends on this. Boards employed in flooring houses are from an inch to an inch and a half thick. The best floors are those that are laid with the best battens.

BOARDING-JOISTS, are those joists in naked flooring to which the boards are fixed.

Boarding, *Luffer.* *See* Luffer-Boards, and Lever-Boards.

Boarding for Pugging or Deafening. *See* Sound-Boarding.

Boarding for Slating, are boards nailed to the rafters for fixing the slates. They are in general about three-quarters or seven-eighths of an inch thick, the sides are most commonly rough, the edges either rough, shot, plowed and tongued, or rebated, and sometimes sprung, that is, beveled, so as to prevent the rain from running through the joists. Boarding for slates may be made so as to take away the lateral pressure from the walls, by disposing the boards in the form of a truss. Upon the lower edge of the boarding must be fixed the eaves-lath or board, and also against all walls that are either at right angles to, or forming an acute angle with the ridge, or a right or obtuse angle with the wall-plate. The eaves-lath at the bottom is for raising the lower ends of the under row of slates which form the eave. Those placed against walls in the positions now mentioned are for raising the slates, in order to make the water run off from the wall, as otherwise it would make its way below the lead and down the joint, between the end of the slates and the wall. Boarding for slates should be yellow deal without sap, which, as well as weather-boarding, is measured by the superficial foot, and valued in the bill by the square of one hundred superficial feet.

Boarding for Leaden Platforms and Gutters, is seldom less than one and one eighth, or one and one-quarter inch thick, most frequently with rough joints only.

Boarding for Lining Walls, is commonly about five-eighths or three-quarters of an inch thick, plowed and tongued together.

Boarding for outside Walls. *See* Weather-Boarding.

BOARDS, *Listed*, are those reduced in their breadth by taking away the sap-wood.

Boards, *Lever*, are those placed in the opening of an aperture made to turn on centres at the ends, in one movement, so as to admit or exclude the air at pleasure.

Boards for the Valleys of a Roof. *See* Valley-Boards.

BOASTER, or Boasting-Tool, in masonry. *See* Masonic Tools

BOASTING, in stone-cutting, is pairing the stone with a broad chisel and mallet, but not in uniform lines.

Boasting, in carving, is the rough cutting round the ornaments, so as to reduce them to their contours or outlines, before the incisions are made for forming the raffels or minute parts.

BODY of a Niche, is that part of the recess which has its superficies vertical. If the lower part is cylindrical, and the upper part spherical, the lower part is the *body*, and the upper part is called the *head*. *See* Niche.

Body of a Room: where there are recesses in the ends or sides, the principal part, from which the recesses are made, is called the body.

Body Range of a Groin. When two openings intersect each other, the widest is called the *body range*. *See* Groin.

BOFFRAND, Germain, an architect born at Nantes, in 1667, and died at Paris, aged eighty-seven. He built several grand edifices, and executed a number of bridges, canals, &c. He also wrote on the principles of architecture.—*D'Argenville Du Fresnoy.*

BOLSTERS. *See* Balusters of the Ionic Capital.

BOLT, in joinery, an iron fastening for a door, moved by the hand, and catching in a staple or notch to receive it.

Bolts are of various kinds: *plate*, *spring*, and *flush bolts*, are for fastening doors and windows.

There are also round bolts of various sizes, for large doors and gates, and some curious brass bolts for folding-doors, which have plates set on the edge of the door, extending the whole length, so that by a turn of the knob-handle in the centre of the door, the bolts shut up and down at the same time; and by turning the contrary way the bolts are relieved, and both doors open at once, without further trouble; these are mostly used when it is necessary to lay two rooms into one. As these bolts are expensive, there are others nearly on the same principle, denominated *spring-latch bolts*, about thirteen inches long, with a stout plate: two of these are required to a pair of doors, one at the top, and the other at the bottom: each bolt is shut by a spring, against which the right hand presses, and being shut, both are secured.

Bolt of a Lock, the iron part by which it is fastened into the jamb, in the act of turning it by the key. Of these there are two kinds: one, which, in the closing of the door, shuts of itself, and is called a *spring-bolt;* the other, which is shut by the key, is called a *dormant-bolt.*

Bolts, are also large iron cylindrical pins, with round knobs at one end of a greater diameter, and a slit at the other end, through which a pin or fore-lock passes, for making fast the bar of a door, window-shutter, or the like. These are particularly called *round-bolts*, or *window-bolts.*

Bolts of Iron, in carpentry, are those square or cylindrical pins which pass through two or more pieces of timber, with a broad knob at one end, and a nut screwed to the other, for securing them together. Bolts of this description must always be proportioned to the size and stress of the timbers so connected.

BOMON, in Grecian antiquity, an altar to a god.

BONANNO, an architect who flourished about 1174. He built the famous tower at Pisa, in conjunction with Guillaume, a German.—*Felebien.*

BONARROTTI, Buonaroti, or Bonarota, Michael Angelo, a celebrated painter, sculptor, and architect, born at Chiusi, in Tuscany, in the year 1474. His talents were so early developed, that he is figuratively said to have been *born a painter;* and his parents, observing the turn of his genius, put him under the tuition of Dominico Ghirlandaio, whom he soon surpassed; for at the age of sixteen he executed some pieces rivaling even those of antiquity. Under the auspices of that great patron of the arts, Lorenzo di Medicis, he established an academy for painting and sculpture at Florence; which on account of the troubles of the house of Medici, he afterwards removed to Bologna. At the age of twenty-nine, he was employed by Pope Julius II. to construct a grand mausoleum; but before it was finished, he returned to Florence in disgust, on account of some pecuniary matters. From Florence he would have gone to Constantinople, whither he had been invited by the grand signor, to build a bridge from that city to Pera, had he not been prevailed upon to return to Rome by Soderini, the gonfalonier, or holy standard bearer. This officer recommended him to his brother, Cardinal Soderini, who introduced him to the pope, at Bologna. Here he met with an envious competitor, in the person of Lazzari Bramante d'Urbino, who had been employed by the pope, and was unwilling to share his honours and profits with another. He endeavoured to excite a spirit of discontent in Bonarrotti, by insinuating that the pope was too much offended at his former conduct, to permit him to resume the building of the mausoleum; and to the pope he represented, that as Bonarrotti was a painter, he might be more advantageously employed in painting the arch of the Sextine chapel, at Rome, than in any other work. It should seem from this, that Bonarrotti had not yet displayed those talents as a painter, with which he afterwards fascinated the world; for it is certain that Bramante, considering him as a dangerous rival, meant nothing less than his complete disgrace. Bonarrotti, however, though contrary to his inclination, painted the arch,

so much to the pope's satisfaction, that he was taken into greater favour than ever.

Pope Leo X. ordered him to make a design for the front of the church of St. Laurence, at Florence, for which also several other architects had given a drawing, but Bonarrotti's being preferred, he was sent to Florence to superintend the building; the vestry of which is reckoned among his best productions. In this city he also built the Medicean Library, the niches and staircase of which are of very curious construction.

On the death of Sangallo, in 1546, the pope, Paul III., appointed Bonarrotti architect of St. Peter's, at Rome, an appointment which he at first declined; but being vested with unlimited powers for carrying on the work, he not only accepted it, but even refused any remuneration for his labours. Sangallo had left a model for finishing the building, which had cost 4184 Roman crowns, and occupied some years in making; according to which the edifice itself could not have been completed in fifty years and upwards. The first use Bonarrotti made of his extensive commission was to set this model aside; and in fifteen days he produced another, for the small cost of twenty-five crowns, by which he proposed to raise that venerable pile with far greater facility and expedition, and with more majestic grandeur, than the plans of any of his predecessors could have given it. The four great piers, by which the cupola was to be supported, had been erected by Bramante, but they were so very weak, that succeeding architects had found it necessary to strengthen them. Bonarrotti thinking them still insufficient for the purpose, he enlarged them to their present gigantic size, and contrived to leave voids, like wells, in them, probably for the purpose of keeping them dry. Similar vacuities he left in the principal walls, through which he carried a winding staircase, so wide, and upon so gentle an ascent, that he was enabled to convey materials to the height of the level of the arches on beasts of burden. The great cornice over the arches differs from the common cornice, in having less projection and fewer members; and the imposts of the pilasters have a greater projection. In each of the two curved extremities of the transept, it had been intended by former architects to place eight tabernacles, or altars; but Bonarrotti reduced their number to three, and threw an arch over them, subdivided into a few well-proportioned compartments; and to prevent any alteration in his design by future architects, he built the whole so solid that it could not conveniently be changed. He lived, however, to see the building carried to the height of the tambour on which the cupola was to be laid, when, on account of his age, his friends urged him to frame a model of the dome, lest what he had already done should be spoiled by the incapacity or whim of a succeeding architect. With this request he complied, and formed one of clay, which he afterwards caused to be made of more durable materials, by Giovanni Farnese. This model was universally approved, and finally executed in the pontificate of Sextus V. While Bonarrotti was engaged in the building of St. Peter's, the officers called *conservators*, in the time of Paul III., resolved to reduce the Capitol to a useful and convenient shape, for which purpose they applied to Bonarrotti. He accordingly began the Senators' Palace, in the centre, ascended from without by a double flight of steps, landing on a level introduced between the two flights. The wing, denominated the *Conservatorium*, is entirely from his design. The ground-floor consists of an external and an internal portico, supported by sixty-eight columns of the Ionic order, surmounted with that elegant capital, the invention of which is attributed to himself. There is, however, a great blemish in this part of the building; for, in order to give a due proportion to the width of the portico, the columns are niched into the wall, an expedient never productive of beautiful effect. About this time, he also finished the Farnesian Palace, which had been begun by Sangallo. He likewise designed and executed the gate, called *Porta Pia*, the architecture of which is not very regular; of many other gates designed by him, it is uncertain whether any of them were ever constructed, but they are all of the same irregular taste. The great central hall of the Dioclesian baths was converted into a church from a design of his; as were the chapel of the Strozzi family at Florence, and the college of the Sapienza. except the part where the church is situated; it is upon the whole a very fine edifice.

Old age having at length rendered this great architect incapable of personal exertions, Nanni Bigio was secretly commissioned by the pope to superintend the building of St. Peter's, but with strict orders to adhere minutely to the plans and model of Bonarrotti, who died in 1564, in his 90th year, before the dome was completed. His body was transported to Florence by order of Comes de Medicis, where it received the most splendid funeral honours, and a superb mausoleum was erected to his memory, at the expense of the grand duke.

BOND, in building, in a general sense, is the manner of making two or more bodies fast together.

Bond, in masonry, or brickwork, is the disposition of stones or bricks in building. It is a principle in every kind of bond to prevent vertical joints falling upon one another. When a course of masonry has any number of stones placed at regular intervals in the length of that course, and the lengths of the stone placed in the thickness of the wall, and when there are two or more intermediate stones in the same course, with their lengths placed horizontally on the facing or surface, between each two of the former stones: this kind of bond is called *header and stretcher*. The stones which have their length placed in the thickness of the wall are called *headers*, and those which have their longest horizontal dimensions placed in the exterior, or front, are called *stretchers*.

Where masonry consists of rubble-work, and where the stones are not disposed in courses, the jambs of apertures, should there be any, are generally built with ashlar; every second stone in the height of each jam is inserted so as to pass through the whole thickness of the wall; and the horizontal dimension on the facing of every intermediate stone is much greater than that of those which are inserted the whole thickness. The stones that are inserted the whole thickness of the wall are called *heading jambs*, and the intermediate stones which have their length placed horizontally in the face, are called *stretching jambs*.

Bond, *Heart*, in masonry, is, when two stones which appear in the front and rear of a wall meet in the centre of it, and when a third stone is placed over the joint, in order to bind the facing and backing together, where otherwise it would be expensive to insert stones the whole thickness of the wall.

Bond-Stones, are those used in uncoursed rubble walling, that have their longest horizontal dimensions placed in the thickness of the work: these should be placed at regular intervals, both altitudinally and horizontally, so that every stone of one row may fall between every two of each adjacent row. Bond-stones that are inserted the whole thickness of masonry are called *perpends* or *perpend-stones*. Bond-stones only differ from headers in this, that bond-stones are used to bind rubble and brickwork, and headers are laid in regular courses, with an equal number of headers between every two stretchers.

Bond, *English*, is, when every two courses of bricks with the length of the bricks inserted in the thickness of the wall,

has one course between them, with their lengths placed horizontally in the front of the wall: the courses in which the length of the bricks is placed in the thickness of the wall, are called *heading-courses;* and those which have the length of the bricks placed horizontally in the face of the work, are called *stretching-courses.*

Bond, *Flemish*, in brickwork, is that which has one header between every two stretchers, and one stretcher between every two headers throughout the same course.

This is considered the neatest and most beautiful; but is attended with great inconvenience in the execution, and in most cases does not unite the parts of a wall with the same degree of firmness as the English bond.

Those who are desirous to enter into an examination of the comparative merits of these two species of Bond, will be gratified in the perusal of Mr. G. Saunders' Tract on *Brick-bond;* it is sufficient in this place to observe generally, that whatever advantages are gained by the Flemish Bond in tying a wall together in its thickness, are lost in the longitudinal bond; and *vice versâ.* To remove this inconvenience, in thick walls, some builders place the bricks in the core at an angle of forty-five degrees, called *herring-bone*, parallel to each other throughout the length of every course, but reversed in the alternate courses; so that the bricks cross each other at right angles. But even here, though the bricks in the core have sufficient bond, the sides are very imperfectly tied to the core, on account of the triangular interstices formed by the oblique direction of the internal bricks against the flat edges of those on the outside.

With respect to English bond, it may be remarked, that as the longitudinal extent of a brick is nine inches, and its breadth four and a half; it is usual—to prevent two vertical joints from running over each other at the end of the first stretcher from the corner, after placing the return corner stretcher, which becomes a header in the face that the stretcher is in below, and occupies half the length of this stretcher—to place a quarter brick on the side, so that the two together extend six inches and three-quarters, leaving a lap of two inches and a half for the next header. The *bat* thus introduced is called a *closer.* A similar effect might be obtained by introducing a *three-quarter bat* at the corner of the stretching course, and then the corner header being laid over it, a lap of two inches and a half will be left at the end of the stretchers below, for the next header, which being laid, the joint below the stretchers will coincide with its middle.

Bond-Timbers, are those horizontal pieces, built in stone or brick walls, for strengthening the building, and securing the battening, lath, and plaster: also the horizontal mouldings, or finishings of wood.

Bond-timbers disposed in tires, at altitudes corresponding to those of the horizontal mouldings, in the finishing of apartments, as behind skirtings, bases, and surbases, are called *common-bond;* the scantling of which is generally four inches broad in the thickness of the wall, and two inches and a half thick in the altitude of the wall, so as to be equal in thickness to a course of bricks. Bond-timbers placed in or near the middle of the story, of eight inches wide in the thickness of the wall, and five inches and a half deep (or about the length and thickness of two bricks) in the altitude of the wall, are called *chain-timbers*, or *chain-bond.* In brick buildings, when the lintels of a range of windows are considerably below the ceiling, the lintels may be continued through the walls as bond-timbers: in this case the thickness of the bond-timbers should be regulated by the necessary thickness of the lintels. When bond-timbers are also the wall-plates of floors or roofs, their scantling is generally the same as that of the chain-bond. The whole of the plate and chain-bond should be continued on one side of each internal wall, where the funnels or flues permit, as well as on the inside of the external walls, and properly notched and fastened at the angles. Bond-timbers will, in most cases, prevent a building from cracking, where the foundation is infirm: they are easily executed in brickwork, or in coursed stone-work; but in rubble-stone it is difficult, as the work must be leveled at every height in which they are disposed; for which reason plugging is preferable in such work. Plugging has one very material advantage over bond-timbers, that in case of fire, the walls are less liable to tumble or warp, for they are not reduced in their thickness; but this must be the case where bond-timbers are employed, as they form a part of the thickness of the walls themselves. Bond-timbers should be avoided in damp situations, such as basements of houses, as they are liable to rot and thus render the buildings insecure.

Within the last few years, a practice has arisen of introducing iron-hoop in place of bond-timber. Several strips or lengths of hoop are laid on at every four or five courses of bricks, and worked in as bond-timbers are—sometimes they are placed at intervals of three or four feet in the height of walls. It is pretended that great advantages, as regards danger from fire, result from this practice, but we are strongly inclined to the opinion that whatever good may arise from the incombustible nature of the material, is more than counterbalanced by the absence of the same strength as that given by timber-bond.

Bonds, are all the timbers disposed in the walls of a house, such as bond-timbers, lintels, and wall-plates. *See* Fir, in Bond.

Boning, in carpentry and masonry, is the act of making a plane surface by the direction of the eye. It is by boning with two straight edges that joiners try up their work, whether it be in or out of winding, that is, whether the surface be twisted or a plane. Many country masons and bricklayers level the tops of their walls without an instrument, by boning them with the contour of the surface of the sea, where it is not apparently terminated with land on the other side. This mode comes so near the truth, even though the building be raised a considerable distance above the surface of the water, that the difference cannot be perceived upon the common levels.

BONOMI, Joseph, an architect, born in Italy, and died in 1808. He was an associate of the Royal Academy in London. He built several mansions and villas, and was esteemed an artist of superior ability.

BOOTH, a temporary wooden building.

BORDERS, are three pieces of wood which are generally mitered together round the slab of a chimney, flush with the surface of the floor.

BORING, the act of perforating a solid. For the purpose of boring wood, joiners use a centre-bit, nose-bit, shell-bit, and auger-bit, each kind of which is of many sizes. *See* Bit.

BORROMINI, Francisco, born in 1599, in Bissone, diocese of Como. His father was an architect, and much employed by the Casa, or family of Visconti. Francisco was sent, at an early age, to Milan, to study sculpture; and, at seventeen years of age, he went to Rome to be instructed in architecture, by his relation, Carlo Maderno, who also had him instructed in geometry. Maderno set him to take fair copies of his drawings, and made him execute the cherubim on either side of the small doors of St. Peter's, which, with the drapery and festoons over the arches, are the only works of Borromini's chisel. He delighted in painting, and some of his pictures are very good, among which is one of the fathers della Chiesa Nuova, in Rome. On Maderno's death, Borromini was made architect of St. Peter's and

remained a little while under the direction of Bernini; but becoming first emulous of him, then envious, and finally his enemy, he endeavoured to get more commissions for work, and in fact was employed in a vast number of buildings, where, trying to surpass Bernini in novelties, he laid aside the common rules, and bewildered his imagination and talents in a labyrinth of extravagances. At the bottom of the court of the Sapienza, he built a church with a concave front, on a polygonal plan, with its sides alternately concave and convex; the exterior of the cupola, which is surrounded above by a balustrade, has a similar figure; the convex part being formed into steps, interrupted by buttresses. But the lantern is still more whimsical, having its vase in a zig-zag form, on which is erected a spiral staircase, sustaining a crown of metal with a ball and cross at top. However, the greatest delirium of Borromini, is the style of the church of San Carlino alle Quattro Fontane. So many right, concave, and convex lines, so many columns upon columns of different proportions, with windows, niches, and sculptures, in so small a front, cannot but excite pity for the derangement of the mind by which they were projected. The oratory of the fathers della Chiesa Nuova, has likewise its front composed of orbiculated and right lines; where everything is deranged and out of order: undulating coronæ, which, instead of helping the discharge of the water, retain it; delicate mouldings under great weights; mouldings of a strange and new form; breaks only in the architrave of the entablature; prominences, contortions, and every kind of absurdity. There appears, nevertheless, in this building a something harmonious and handsome, but better adapted (as Bernini said) to a country-house or villa, than to the second edifice of a city. The flat arch of the oratory is rather wonderful, being of a much larger size than that of Santa Martina, made by Cortona. Though it supports above it the weight of the great library, the wall of one of its larger sides is not flanked with counterforts, but stands insulated, fronting the street. The habitation of these fathers of the oratory, is one of the best buildings of Borromini, yet it is not without its whimsicalities, in the porticos and loggias of the cloisters, supported by a single Composite pilaster: the tower of the clock is likewise mixtilinear. The best work of Borromini, is the front of St. Agnes, in the Piazza Navona. The king of Spain, wishing to modernize and enlarge his palace at Rome, Borromini was commissioned to do it; for which purpose he made a drawing, and though it was never executed, it gave such satisfaction, that the monarch honoured the author with the cross of St. James, and made him a present of 1000 dollars. Pope Urban VIII. likewise created him knight of Christ, gave him 3000 dollars, and settled an annual pension on him. Part of the palace Barberini; the whole of the monastery and church of the Madonna de' Sette Dolori, at the foot of San Pietro Montorio; and the palace of Rufina, at Frescati, were built by this architect; he also modernized the palace Falconnier, and embellished that of Spada. Besides these, he executed many other works, and sent to various countries designs of buildings, which produced him fame and riches. Borromini was one of the first men of his age for the elevation of his genius, and one of the last for the ridiculous use he made of it. The frenzy which he had displayed in scientific pursuits, extended, as he advanced in years, to moral objects; and he at length died, a lunatic, by his own hands, in 1667.

BOSS, a projecting ornament placed on the intersections of groins, usually carved in the form of a leaf or other ornamental foliage, or, in the later periods of Gothic architecture, richly sculptured with armorial bearings. Bosses were employed in vaulting, not for mere ornament, but formed an essential feature in the construction, as they tended by their weight to retain the voussoirs in their respective positions, and to confine the arches, so as to counteract any tendency to upward motion; they formed, in fact, the key-stones of the vault, binding the whole work firmly together.—Bosses are used in other situations as ornaments to mouldings, &c.

Boss, among bricklayers, a wooden vessel in which the labourers put the mortar to be used in tiling. It has an iron hook, with which it is hung on the laths or on a ladder.

BOSSAGE, the projection of stones laid rough in a building, to be afterwards carved into mouldings or ornaments. Bossages are also projecting rustic quoins in a building, with indentures or channels at the joints. The channels are sometimes square, sometimes chamfered, or beveled, and sometimes circular.

BOULANGER, Nicholas Anthony, an architect, born at Paris, 1722, and died in 1759, aged thirty-seven. He became so eminent in architecture and mathematics, though entirely of his own study, that he was made engineer to the baron of Thiers, and afterwards appointed superintendent of the highways and bridges. He was author of some articles in the Encyclopedia, and several other works.

BOULDER WALLS, are those built of round flints, or pebbles, laid in strong mortar, used where the sea has a beach cast up, or where there are plenty of flints.

BOUND MASONRY. *See* Stone Walls.

BOUNDARY COLUMN. *See* Column.

BOW, a part of some buildings projecting forward from the face of the wall, and raised from a plan generally on the arc of a circle, so as to form the segment of a cylinder. It is sometimes, however, raised from a plan consisting of three sides, two external obtuse angles, formed by each two contiguous sides, and two internal obtuse angles, formed by the wall and the sides which adjoin thereto. A bow, raised from a polygonal plan, with three, four, or five vertical sides; or a prism so disposed, is termed a *canted* or *polygonal bow*. In some buildings the bow is carried to the whole height, in others, only to one or two stories.

Bow, among draughtsmen, denotes a beam of wood or brass, with three long screws that direct a lath of wood or steel to an arch, used in drawing flat arches, or in projections of the sphere.

BOW-WINDOW, a window projecting from the general face of a building on a curvilinear plan, and rising from the ground or basement. *See* Bay and Oriel Windows.

BOX, in its most general acceptation, denotes a case for holding anything.

Box of a Bib-Saw, two thin iron plates fixed to a handle. In one of the iron plates is an opening to receive a wedge, by which it is fixed to the saw.

Box for Mitering. *See* Mitre-Box.

Box of a Theatre, one of the compartments of a gallery.

Boxings of a Window, are the two cases, one on each side of the window, into which each of the adjacent shutters is folded, when light is require in the room. The leaves which appear in the front of each boxing, are denominated *front shutters;* and those in the back, are called *back flaps.* In order to estimate the breadth of flaps, and the depth of boxing-room; suppose each boxing to be filled with the shutters which are to cover half the breadth of the opening: add the thicknesses of all the folds together, with as many one-sixteenths of an inch as there are breadths, and the sum is the depth of the boxing. Thus, suppose a window to be four feet wide, placed in a brick wall eighteen inches thick, let the sash-frame be six inches thick, and placed four inches and a half from the face of the wall, or the breadth of a brick; this will reduce the wall to seven inches and a hal.

thick; to this add the necessary thickness for lath and plaster, about two inches, gives nine inches and a half for the breadth of the shutter: nine inches and a half will be contained in twenty-four inches, or the half of four feet, twice, with a remainder; therefore there must be three leaves or folds in shutter, viz., a front leaf, and two back flaps. The front eaf should be necessarily the whole breadth of the boxing, or nine inches and a half; and the two back flaps between them, the remainder between nine inches and a half and twenty-four inches, that is, fourteen inches and a half. The back flap should always be the least, in order that the shutters may go freely into the boxing; the middle one, therefore, may be eight inches, and the back one six inches and a half, for $9\frac{1}{2}+8+6\frac{1}{2}=24$; but if the flaps are rebated into one another, which is most commonly the case, whatever be the breadth of the rebate and the number of them, then so much more ought to be added to the whole breadth. In the present example, the three folds will require two rebates; let each rebate be a quarter of an inch, then, instead of reckoning twenty-four, it must be twenty-four inches and a half, and as no alteration can be made on the front flap, it must be added to one of the back flaps; the three flaps may therefore stand thus, $9\frac{1}{2}+8\frac{1}{2}+6\frac{1}{2}=24\frac{1}{2}$. Besides this allowance in breadth, there is another for the rebate at the meeting in the middle of the window of the two back flaps; if this rebate be a quarter of an inch also, it may be added to the shutters on either side of the window, or it may be divided in any proportion between; let it be equally divided, then the breadth of the flaps may stand thus, $9\frac{1}{2}+8\frac{1}{2}+6\frac{5}{8}=24\frac{5}{8}$. To find the thickness, suppose the front flap to be one inch and a half, the two back flaps each one inch and a quarter, then $1\frac{1}{2}+1\frac{1}{4}+1\frac{1}{4}+\frac{3}{16}=4\frac{3}{16}$, for the depth of the boxing-room. If there is a back-lining, that must be taken also into the account. When shutters are in many folds, they are troublesome to shut, and this must always be the case in thin walls, or with wide windows. To remedy this, the architraves are either made to project considerably before the plaster, or the lath and plaster are brought to a considerable distance from the rough wall.

BOYLE, Richard, Earl of Burlington. Never was protection and great wealth more generously and more judiciously diffused than by this great person, who had every quality of a genius and an artist, except envy. He spent great sums in contributing to public works, and was known to choose, that the expense should fall upon himself, rather than that his country should be deprived of some beautiful edifices. His enthusiasm for the works of Inigo Jones was so active, that he repaired the church of Covent-Garden, because it was the production of that great master. With the same zeal for pure architecture, he assisted Kent in publishing the designs for Whitehall, and gave a beautiful edition of the *Public Baths*, from the drawings of Palladio, whose papers he procured with great cost. Besides the works on his own estate at Lonsborough, in Yorkshire, he new-fronted his house in Piccadilly, built by his father, and added the grand colonnade within the court. The other works designed by Lord Burlington, were the dormitory of Westminster school; the Assembly-Room at York; Lord Harrington's at Petersham; the Duke of Richmond's house at Whitehall; and General Wade's in Cork street.

BRACE. *See* Truss, and Angle-Braces.

BRACKET, a small support fixed against a wall to sustain anything. Brackets are composed out of various materials—wood, stone, metal, &c., and may be made susceptible of any ornamentation.

Bracket for Shelves. When the shelves are broad, the brackets are small trusses, consisting of a vertical piece, a horizontal piece, and a strut; but when the shelves are small, the brackets are solid pieces of boards, most commonly with an ogee figure on their outer side.

Brackets in Gothic architecture are usually of very elegant design, and are mostly sculptured to represent angels, heads, foliage, and many other beautiful devices. They are used to support statues under niches, pillars which have their basis on a height above the ground, and for various other purposes.

Brackets for Stairs, are sometimes used under the ends of wooden steps, next to the well-hole, by way of ornament, for they have only the appearance of support.

BRACKETING, a disposition of small pieces of board, equidistantly placed in the angles formed by the ceiling and the walls of an apartment, with their planes at right angles to the common intersection, so as to be partly upon the ceiling and partly upon the walls; their faces or hedges being so arranged, as to touch any level line that is everywhere equally distant from the wall or walls which may form the perimeter or circumference of the apartment. The level line equidistant from, or parallel to the walls, will either be a straight line or curve, according as the walls are carried upwards from a straight or circular plan.

Bracketing is necessary in supporting the lath and plaster of cornices and coves. The edges of the brackets to which the lath is fixed, are so formed as to be as nearly equidistant from the surface of the intended cornice or cove as possible, and may be placed about an inch within the said surface. Their common distance from middle to middle may be about a foot or fourteen inches. Small cornices require no brackets; but in large cornices, and particularly in coves, they are indispensably necessary, to save the plaster. In apartments formed by walls with plain surfaces, besides the brackets which are arranged at right angles to the line of concourse of the ceilings and the walls, there are other brackets placed, one in each angle, in a vertical plane, bisecting the angle formed by each two adjacent sides of the room, at the mitre of the cornice, denominated *angle-brackets*.

Let Fig. 1 be the plan of the end of the room, the internal side being A B C D E F G H, and let there be a break, C D E F, as the breast of a chimney. Let Fig. 2 be part of the plan enlarged, showing an internal angle at C, and an external angle at D: let N O P Q represent the face of the rough wall, and B C D E the finish of the plaster; then the space between N O and B C, O P, and C D, P Q and D E will be the space for the battening, lath, and plaster. Let Fig. 3 be a section of the cornice, intended to be run by the plasterer, and let the shadowed part be the form of the common brackets: let I K, I K, &c., Fig. 2, be the projections or seats of the common brackets, each equal to A B, Fig. 3, and let L O and M P be the seats of the angle-brackets; L O being that of the internal bracket, and M P that of the external bracket. Besides the projection beyond the finishing surface of the plaster, there must be added the thickness of the battening, lath, and plaster. As the lath terminates upon the angle-brackets, and as they require to be ranked in the same surface with the edges of the common brackets, they are here made double, or in two thicknesses. Let it now be required to find the form of the brackets, either for mouldings, as Fig. 3, or for a cove: make A B, Figs. 4 and 5, equal to the projection of the common bracket; draw B b perpendicular and equal to A B, and join A b: place or draw the form of the bracket with the ceiling edge of it upon A B: take any number of points, G, H, I, K, &c., in the ranging edge of the bracket, at the concourse of every two lines, or in the curve, and draw G A, H C, I D, K E, &c., perpendicular to A B: produce H C, I D, K E, &c., to meet A b in c, d, e, &c., draw A g, c h, d i, e k, &c.,

perpendicular to A b, and make A g, C h, D i, E k, &c., each equal to A G, C H, D I, E K, &c., and join the points g, h, i, k, &c. if the ranging edge of the common bracket is made of straight lines; or draw a curve if the common bracket is a cove: then will A g, h, i, k, &c. to b, be the form of the angular bracket, whether for the external or internal angle, and g, h, i, k, &c., the ranging edge; the parts G H and g h are supposed to be within the finished surface of the plaster. Fig. 6 shows the bracket for an acute angle, and Fig. 7 for an obtuse angle; but except the quantity of the angle, the method of finding the forms is exactly the same as in Figs. 4 and 5. The common bracket of Figs. 4, 5, and 7, is laid down upon the ceiling line; but that of Fig. 6 is laid down upon the base line. In the common brackets of Figs. 5 and 6, the projections and heights are equal; but in Fig. 7, the height B C is greater than the projection A B: the shadowed parts of Figs. 6 and 7 represent the thickness of the battening, lath, and plaster. Figs. 8, 9, 10, 11, show the ranging both for external and internal angles. *See* RANGING.

BRACKETING, for lath and plaster, is variously named according to the figure of the ceiling which it sustains: as *groin-bracketing*, *spandrel-bracketing*, &c. In all cases the brackets are so disposed, that their edges will be parallel to the surface of the plaster when finished: the distance between the edges of the brackets and the surface of the plaster, is, in general, about three-fourths or seven-eighths of an inch, which includes the space for battening, lath, and plaster. *See* COVE, DOME, GROIN, PENDENTIVE, SPANDREL, SPHERICAL, and SPHEROIDAL BRACKETING.

BRADS, in joinery, are slender nails without spreading heads, except a projection from one of their narrow sides. The intention is to drive them within the surface of the wood, by means of a hammer and punch, and fill the cavity to the surface with putty, and thus conceal them entirely. There are several kinds of them, as *joiners' brads*, *flooring brads*, &c.

BRAMANTE, LAZZARI, D'URBINO, a celebrated architect, born at Castel Durante, (or according to some accounts, at Femagnano,) in the province of Urbino, about the year 1444. The family of which he was a branch, was poor, though respectable, by whom he was designed for a painter: his early years were spent in the study of this art, but his taste and talents for architecture outran every other consideration, till at length he devoted himself altogether to it. He travelled first in Lombardy, and having made some observations on the cathedral of Milan, he went to Rome, where he executed some paintings for the church of St. John de Lateran, which are now lost. His great care was to examine and measure all the precious remains of antiquity, both within and out of Rome: he measured all that he could of the Villa Adriana, at Tivoli; and in pursuit of similar objects, went even so far as Naples.

This devotedness to his favourite science attracted the notice of many patrons of the fine arts, and among the rest, of Cardinal Oliviero Caraffa, who employed him to rebuild the convent della Puce, at Naples, which established his reputation. The work itself is not of the most exquisite character, but it procured him the title of architect to his holiness Pope Alexander VI., there being at that time no artists of superior talents in the papal dominions. The fountain of Trastevere, and another fountain, which formerly stood in the square before St. Peter's, were of his workmanship. He also had a considerable share in building the palace della Cancellaria, the church of St. Lorenzo Damaso, and the palace of San Giacomo Scosciacavalli; all these, as well as the convent della Puce, above noticed, are built in travertine, on the outside; but their meagre style is a striking evidence that in the days of Bramante architecture was only reviving, and was not completely purged from barbarous intermixtures. In such an age the genius of Bramante could not but shine, and he retained his lustre as being without an equal in invention, as well as in execution, till, towards the decline of his life, the superior powers of Michael Angelo Bonarrotti bore away the palm of science, and the voice of public applause. *See* BONARROTTI.

When Julius II. obtained the papal chair, he appointed Bramante superintendent of his buildings, and employed him to execute his grand project of uniting the Belvedere to the palace of the Vatican, by means of a magnificent court. In his turn, Bramante engaged the pope in the favourite design of pulling down the church of St. Peter's, and erecting a new basilica, after the model of the Pantheon, on a scale that should astonish the world. With this view, he made many drawings, and used great diligence to produce one having two steeples with the front between them, as may be seen on the medals struck by Corodasso, in honour of Bramante and his patrons Julius II. and Leo X. The plan was that of a Latin cross, and was well constructed, though of an unequalled magnitude. Three naves were formed by means of colonnades; the principal nave of very fair proportions, and the whole productive of the finest effect. The cupola had the same dimensions with that of the Pantheon; the external steps were also similar. Indeed, the plan of the whole basilica bore a strong resemblance to the Pantheon, having eight piers, between each two of which were two columns, forming three openings, or passages. This design being approved of by the pope, part of the old church was pulled down, and the foundation of the new structure laid, in the year 1506. The building was carried on with great celerity as high as the entablature, the arches over the four great piers were turned, and the principal chapel, opposite the door, was erected, when death put an end to his labours, in 1514, in his 70th year. The continuation of this work was given to Michael Angelo Bonarrotti, who also did not live to see it completed. Bramante's successors made so many alterations upon his original design, that scarcely anything besides the four great arches over the tribune can be said to be his. His remains were interred in St. Peter's, and the solemnity was honoured by the presence of the papal court, and all the professors of the fine arts in Rome and its neighbourhood.

Besides the works above described, Bramante constructed a whimsical staircase, with the three orders of architecture, in the Vatican. The elegant circular temple in the cloister of San Pietro Monterio, though esteemed as one of his best performances, has many defects; for instance, the doorway cuts into two pilasters; the balustrade is a continued series of balusters without pedestals; and the ornament at the top of the cupola is clumsy and heavy. Out of the walls of Todi, Bramante built an insulated temple, encrusted on the exterior with white stone; the plan is that of a Greek cross, with a fine cupola in the centre; and the whole has an air of being the model of St. Peter's. In finishing the chapel within the basilica, he revived the use of the ancient stuccos. He made many designs of palaces and temples, both within and without the walls of Rome, and began the palace, which was afterwards finished by Raffaello, with columns of brick covered with plaster, then a new invention; but this edifice was destroyed to make room for the colonnade of St. Peter's; and the palace which he began for the Duchess Eleonora Gonzaga, wife of Francis Duke of Urban, was never completed, owing to the deaths of both duke and duchess.

BRANCHES, are the diagonal ribs of a Gothic vault, rising upwards from the tops of the pillars to the apex, and seeming to support the ceiling or vault.

BRANDRITH, or BRANDRETTE, a fence round the mouth of a well.

BRASSES, sepulchral engravings on large or small brass plates, let into slabs in the pavement of our ancient churches, portraying the effigies of illustrious personages, with the accompaniments of buildings, &c. The greater part of the effigies are as large as life. The various colours for the dresses, armours, and coats of arms, in many instances, were laid on in enamel, the attitudes well drawn, and the lines both of dresses and architecture made out with precision and truth of imitation.

BREADTH, the greatest extension of a body at right angles to the length.

BREAK, a projecting part of the front of a building, carried up through one or more stories in a vertical surface. In its general acceptation, it implies only a part, which stands forward in a plane parallel to the other parts of the front behind the break; or a cylindric wall concentric with a receding one, and in this it comprehends not only the parallel projecting face, but the two flank parts which join the parallel walls. The break therefore forms, with the receding part or parts, two external and two internal angles. The term is, however, not restricted to this disposition of the planes, or cylindric faces of the building, it may also imply a bow, whether cylindric or canted. No break can be formed unless it have at least one internal angle, or, if the building adjoin on both sides, there will be at least two internal angles. Small breaks, or those projecting only a few inches, never add to the effect of the building.

A building may have either one, two, or several breaks in a front. When the disposition of the rooms naturally falls into the same plane on the inside of the front wall, no break should be admitted, because, in this case, it can only project a few inches. Breaks only fritter away the parts of a small building, and destroy the beauty and elegance which arises from the simplicity of its figure; but in large buildings they give the utmost splendour to the design, provided they have bold projections, and appear as distinct parts of the building, so that if the other connecting parts be supposed to be taken away, they would be so many insulated buildings, insisting each upon a simple rectangular plan. The greatest effect would, therefore, be produced by giving each part or break its separate roof, termination, or covering. For this reason, breaks should either be left lower, or carried higher than the main body, or the connecting part or parts of the building. When a break is carried higher than the connecting part or parts, it must have an entire roof, or uniform termination all round its four walls.

In the ancient architecture of Greece, the walls insisted upon simple rectangular plans, and therefore had no internal angles, and consequently no breaks. The Romans indulged in buildings consisting of greater variety of parts than the Greeks, and formed many of their principal edifices with breaks.

When the upper part of a front wall is intended to be one continued plane, with a break or breaks in the lower part or story, the superior continued wall may either be supported upon a row of columns arched above the intervals in long apartments, or with one arch, when the front horizontal dimension is small, and finished as above.

Breaks in cylindric walls destroy the harmony arising from the continuity of the figure, and should therefore be rejected in every round edifice.

BREAK-IN, among carpenters, is to cut or break a hole in brickwork with the ripping chisel, for the purpose of inserting timber, as to receive plugs, or the end of a beam, or other piece of timber.

BREAK-JOINT, in masonry or brick-work, is when two stones are placed contiguous to each other, with a third stone laid across the joint, so as to cover a part or the whole of the surface of both stones, in order to bind the work together.

BREAST OF A CHIMNEY. *See* CHIMNEY.

BREAST OF A WINDOW, the masonry or brick-work which forms the back of the recess and the parapet, for leaning upon, under the window-sill.

BREAST WALL, a retaining wall at the foot of a slope.

BRESSUMMER, or BREAST SUMMER, in building, a lintel-beam in the exterior walls, supported by wooden or iron posts, or by brick or stone pillars, for sustaining the superincumbent part of the wall. Bressummers are used in the construction of shops, where it it necessary to have the window as large as possible, and consequently the pillars as small as possible, in order to give light, and show articles for sale to advantage.

Where breast-summers are used for this purpose, the superincumbent mass should be strengthened by an arch of discharge or otherwise, for, if not so, they will be found of great injury to the building through the shrinkage of the timber. Where this precaution is not attended to, it almost invariably occurs that the brick-work above is fractured in its settlement, and in some cases to a very considerable extent.

Cast-iron beams are occasionally used for breast-summers, but although they have an advantage in not being liable to rot, and are naturally incombustible, yet they are by no means eligible for the purpose. Cast-iron should never be subjected to cross strain, as, although it may bear a certain weight with safety, the least addition or disturbance will cause it to break. In cases of fire, cast-iron is much less secure than wood, for it soon becomes red-hot, and in this state, upon the slightest contact with water, will snap asunder; whereas timbers, if of sufficient scantling, are seldom entirely consumed, usually only charred on their exposed surfaces.

Bressummers were a necessary part in the construction of old timber buildings, where it was requisite to have them not only for binding the building together, but for the support of every floor, and also of the roof. They were likewise placed at the bottom of the building as a foundation to the whole structure, and called *sills*. *See* SUMMER.

BRICK, an artificial kind of stone, composed in general of earth and sand, or coal cinders, or ashes, well mixed together, and tempered with water, then dried in the sun, and finally burned to a proper degree of hardness in a kiln, or in a heap or stack, denominated a *clamp*.

The antiquity of bricks seems to be coeval with the first edifices after the Deluge; the tower and city of Babel being built of them; as also most of the early structures of Egypt. The Greeks chiefly used three kinds of bricks: the first sort was called Διδωρον, *bricks of two palms;* the second Τετραδοοον, *of four palms;* the third Πενταδορον, *of five palms.* Besides these, they also had bricks of just half the above dimensions, used for making their work more solid, and for giving an agreeable diversity to its appearance.

The Romans began to build with brick towards the decline of the republic: according to Pliny, those most in use were a foot and a half long, and a foot broad; which agrees with the dimensions of several Roman bricks found in England, viz. seventeen inches in length, by eleven in breadth, of our measure. Sir Henry Walton speaks of some bricks at Venice, of which stately columns were built: they were first formed in a circular mould, and cut, prior to their being burned, into four or more sections; afterwards, in laying they were jointed so closely and exactly, that the pillars had the appearance of being composed of one entire piece.

For the purposes of building, bricks claim a decided superiority over stone, not only as being lighter, and more easily worked; but also because their porous texture facilitates their union with the mortar, and makes them less liable to attract or retain damp and moisture.

In England, the mould in which bricks are formed, is ten inches in length, by five in breadth; the bricks when burned are about nine inches long, four inches and a half broad, and two inches and a half thick. The degree of shrinkage, however, is various, according to the purity and temper of the clay, and the intensity of the heat to which it is exposed in the burning.

The earth selected for brick-making should be of the purest kind; though indeed bricks may be made of any kind of earth that is free from stones, and even of sea-ooze; but it is not every soil that will burn red, which is a property peculiar to earths containing ferruginous particles. In this country, bricks are chiefly made either of stiff clay, or of a hazelly-yellowish-coloured fat earth, commonly called *loam.* The former produces hard red bricks, incapable of rubbing or cutting; the latter is mostly found near London, and gives a neat gray-coloured brick, which yields freely to the axe and rubbing-stone, though equally durable with the harder red brick made in more distant parts. The earth, of whatever quality, should be dug in the autumn, and suffered to remain in a heap till the next spring, that it may be well penetrated by the air, and particularly by the winter's frosts, which by pulverizing the more tenacious particles, greatly assist the operations of mixing and tempering. Indeed, for the best bricks, two or three years will not be found too long to submit the earth to the action of the atmosphere, in order to render it free in the working. In making up this heap for the season, the soil and ashes or sand are to be laid in alternate layers, or strata; each stratum containing such a quantity as the stiffness of the soil may admit or require. For making such bricks as will stand the fiercest fires, Sturbridge clay and Windsor loam are esteemed the best.

In tempering the earth, much judgment is required as to the quantity of sand to be thrown into the mass, for too much renders the bricks heavy and brittle, and too little leaves them liable to shrink and crack in the burning. The London practice of mixing sea-coal ashes, and in the country of adding light sandy earth to the loam, not only makes it work easy and with greater expedition, but tends also to save fuel.

With reference to the proportion which should be observed in mixing the different ingredients, it is impossible to lay down any fixed rules, as such proportion must entirely depend upon the particular quality of the materials employed. The principal of these consist of clay, marl, and loam, with the admixture of sand, chalk, breeze, &c. We shall here give the particular uses to which the accessories are applied, but must leave it entirely to individual instances to determine in what manner each of them must be made use of. The clay of course is the principal matter, and forms the body of the brick, but before this can be made available for building, it has to be agglutinated together by means of sand vitrified by heat. Clay is composed for the most part of alumina and silica combined with a small quantity of lime, and occasionally of magnesia and alkali. Usually speaking, clay requires additional sand to be used as a flux, but it happens sometimes to contain sufficient in itself; when this is the case, no addition of course will be required. If the silica be in excess, it will on the contrary require the addition of some dry substance to hold the mass together, as otherwise the silica will fuse and run when under the action of great heat; for this purpose the chalk is used: if, however, too much be added, the bricks will become porous and friable. The heat, as above stated, is produced by means of the breeze, but the quantity of this also must be regulated according to the nature of the clay you have to use; if it contains a large quantity of sand, less breeze will be required, not only to prevent the silica from running, but also because silica contains a large portion of oxygen: should, however, the clay contain a free proportion of lime, more breeze will be required, for the reason that lime has but little oxygen in its composition. Thus it will be seen how impracticable it is to lay down any general rule in this case; the proportion of each ingredient to be added, can only be determined by careful observations in individual instances.

Every stony particle should be carefully cleared out of the earth, before the workman begins his operation of tempering; it should then be well trodden or beat, and frequently turned over, with the addition of as little water as possible, till the soil and ashes, or sand, are so completely incorporated as to form a paste of a tough viscous substance. If in this operation too much water be used, the paste will become almost as dry and brittle as the soil of which it is composed; but by a judicious management, as to the quantity of water, and the mode of administering it, the bricks become smooth, solid, and durable.

For the preparation or tempering of the soil, the workman is provided with a long hoe, in form like a mattock, a shovel, and a scoop. The hoe is for pulling down the soil from the great heap, which is then chopped backwards with the shovel, in order to turn it as often as may be necessary, and to incorporate the ashes, or sand, and soil, thoroughly together. The use of the scoop is for throwing water over the portion so pulled down with the hoe, to bring it to a more ductile state, and render it easier for tempering. When the mass is sufficiently mixed, it is removed in barrows to the pugmill. This mill consists principally of a strong barrel, firmly fixed on two transverse beams, having in its centre a vertical bar, kept in position by two shoulders attached to the sides of the barrel, and working on the transverse beams at their intersection as on a pivot. On the top of this bar is placed a horizontal beam, by means of perpendiculars suspended from which, the horse is attached. On that part of the bar which is within the barrel, is fixed several iron knives, by the revolution of which the masticated clay is forced through a hole in the bottom of the barrel, when it is cut off in pieces with a "cuck-hold," or concave shovel, and laid on one side. A quantity of sand is then thrown over it, and it is kept for use under a covering of sacking or matting, to preserve it from the sun and air.

The moulding-table is placed under a movable shed, and is strewed with dry sand. A boy, with the cuck-hold, cuts off as much as he can carry in his arms, from the prepared mass, and brings it to the table, where a girl receives it, and rolls out a lump rather larger than the mould will contain. The moulder receives this lump from the girl, throws it into his mould, previously dipped in dry sand, and with a flat smooth stick, about eight inches long, kept for the purpose in a pan of water, strikes off the overplus of the soil: he then turns the brick out of the mould upon a thin board, rather larger than the brick, upon which it is removed by a boy, and placed on a light barrow, having a lattice-work frame raised about three feet above the wheel, and about eighteen inches at the handles, forming an inclined plane. On this lattice-frame the new-made bricks are laid, and sand is thrown over them, to prevent their sticking to each other, as well as to preserve them in a certain degree from cracking in drying on the hacks. The hacks for drying, are each wide enough for two bricks to be placed edgeways across, with a passage between the heads, for the admission of air, to

facilitate the circulation of which, the bricks are generally laid in a diagonal direction. The hacks are usually carried eight bricks high; the bottom bricks at the ends are commonly old ones.

In showery weather, the bricks on the hacks are to be carefully covered with wheat or rye straw, to keep them dry; unless sheds or roofs be erected over the hacks, as is done in some country places; but in London this is impracticable, from the very great extent of the grounds.

In fine weather the bricks will be dry enough for turning, in a few days; in doing which they are reset more open than at first; and in six or eight days more they will be ready for burning.

The best bricks, that is, those made of the best materials, and well tempered, as they are harder and more ponderous, so they require half as much more earth, and longer time for drying and burning, than the common sort, which are light, spongy, and full of cracks. The well drying of bricks before they are burned, prevents their cracking and crumbling in the kiln or clamp.

In the vicinity of London, bricks are commonly burned in clamps; farther in the country it is the custom to burn them in kilns. In building the clamps, the bricks are laid after the manner of arches in the kilns, with a vacancy between every two bricks, for the fire to play through; yet with this difference, that instead of arching, the vacuity for the fuel is spanned over, by making the layers project one over the other from each side, till they meet at top. The flue is about the width of a brick, carried up straight on both sides about three feet; it is then nearly filled with dry bavins, or wood, on which is laid a covering of sea-coal and cinders (or *breeze*, as they are called); the arch is then overspanned, and layers of breeze are strewed over the clamp, as well as between the rows of bricks.

When the clamp is about the width of six feet, another flue is made, in every respect similar to the first; this is repeated at every distance of six feet, throughout the whole clamp, which when completed, is surrounded with old bricks, if there be any on the grounds, if not, with some of the driest unbaked ones, that have been reserved for the purpose. On the top of all, a thick layer of breeze is laid. The wood is then kindled, which gives fire to the coal; and when all is consumed, which will be in about twenty or thirty days if the weather be tolerable, the bricks are concluded to be sufficiently burned. Should there be no immediate hurry for the bricks, the flues may be placed nine feet asunder, and the fuel left to burn slowly.

If the fire in the clamp burns well, the mouths of the flues are stopped with old bricks, plastered over with clay. The outside of the whole clamp is also plastered with clay, if the weather be precarious, or if the fire burn too furiously; and against any side particularly exposed to the rain, &c., screens are laid, made of reeds worked into frames about six feet high, and sufficiently wide to be moved about with ease.

This is the ordinary method of manufacturing common gray-stocks. But washed malms, or marls, are made with still greater attention. A circular recess is built, about four feet high, and from ten to twelve feet in diameter, paved at the bottom, with a horse-wheel placed in its centre, from which a beam extends to the outside, for the horse to turn it by. The earth is then raised to a level with the top of the recess, on which a platform is laid, for the horse to walk upon. This mill is always placed as near a well or spring as possible, and a pump is set up, to supply it with water. A harrow, made to fit the interior of the recess, thick-set with long iron teeth, and well loaded, is chained to the beam of the wheel, to which the horse is harnessed. Previously to putting the machine in motion, the soil, as prepared in the heap in the ordinary manner, is brought in barrows, and distributed regularly round the recess, with the addition of a sufficient quantity of water; the horse then moves on, and drags the harrow, which forces its way into the soil, admits the water into it, and by tearing and separating its particles, not only mixes the ingredients, but also affords an opportunity for stones and other heavy substances to fall to the bottom. Fresh soil and water continue to be added till the recess is full.

On one side of the recess, and as near to it as possible, a hollow square is prepared, about 18 inches or two feet deep. The soil being sufficiently harrowed and purified, and reduced to a kind of liquid paste, is ladled out of the recess, and by means of wooden troughs conveyed into this square pit; care being taken to leave the sediment behind, which is afterwards to be cleared out and thrown on the sides of the recess. The fluid soil diffuses itself over the hollow square, or pit, where it settles of an equal thickness, and remains till wanted for use, the superfluous water being either drained away or evaporated, by exposure to the atmosphere. When one of these square pits is full, another is made by its side, and so on progressively, till as much soil is prepared as is likely to be wanted for the season.

In the country bricks are always burned in kilns, whereby much waste is prevented, less fuel consumed, and the bricks are more expeditiously burned. A kiln is usually thirteen feet long, by ten feet six inches wide, about twelve feet in height, and will burn 20,000 bricks at a time. The walls are about one foot two inches thick, and incline inward towards the top, so that the area of the upper part is not more than 114 square feet. The bricks are set on flat arches, having holes left between them resembling lattice-work. The bricks being set in the kiln, and covered with pieces of broken bricks or tiles, some wood is put in and kindled, to dry them gradually; this is continued till the bricks are pretty dry, which is known by the smoke turning from a darkish to a transparent colour. The burning then takes place, and is effected by putting in brushwood, furze, heath, fagots, &c., but before these are put in, the mouths of the kiln are stopped with pieces of brick, called *shinlog*, piled one upon another, and closed over with wet brick earth. This shinlog is carried just high enough to leave room sufficient to thrust in a fagot at a time; the fire is then made up, and continued till the arches assume a whitish appearance, and the flames appear through the top of the kiln; upon which the fire is slackened, and the kiln cools by degrees. This process is continued, alternately heating and slackening, till the bricks are thoroughly burned, which is generally in the space of forty-eight hours.

The practice of steeping bricks in water after they have been once burned, and then burning them again, renders them more than doubly durable.—*Goldham.*

Many attempts have been made to introduce machinery in the practice of brickmaking, but with little success, as is evident from the old practice continuing so general in use.

The most usual varieties of bricks consist of *marls*, *stocks*, and *place-bricks*, but there is very little difference in the manufacture. *Marls* are prepared and tempered with the greatest care; but the construction of the clamp for burning them is similar to that for other bricks, though more caution is required not to overheat them, and to see that the fire burn equally and diffusively throughout the clamp or kiln. The finest marls, called *firsts*, are selected as cutting bricks, for arches of doorways, windows, and quoins; for which purpose they are rubbed to their proper dimensions and form. The next best, termed *seconds*, are used for principal fronts The cleanly pale yellow colour of marls, added to their smooth texture and superior durability, give them a pre-eminence

above other sorts of bricks. *Gray-stocks* are somewhat like the seconds, but of an inferior quality. *Place-bricks*, sometimes called *peckings*, *sandal*, or *samel-bricks*, are such as, from being outside in a kiln or clamp, have not been thoroughly burned, and are consequently soft, of a more uneven texture, and a red colour. There are also *burrs*, or *clinker-bricks*, such as from being too violently acted upon by the fire, have vitrified in the kiln, and sometimes several are found run together.

Red-stocks are made in the country, and burned in kilns. They owe their colour to the nature of the clay of which they are formed, which is always used tolerably pure. The best sort are used as cutting bricks, and are called *red-rubbers*. In old buildings they are frequently to be seen, ground to a fine smooth surface, and set in putty, instead of mortar, as ornaments over arches, windows, doorways, &c. Though many very beautiful specimens of red brickwork are to be met with, yet these bricks can seldom be judiciously used for the front-walls of buildings. The colour is much too heavy, and in summer conveys an unpleasant idea of heat to the mind; to which may be added, that as in the fronts of most buildings of any consequence, more or less of stonework is introduced, there is something harsh in the contrast between the red bricks and the cold colour of the stones; and even where no stone is employed, there is always some wood used, which being painted white, by no means lessens the bjection. Gray-stocks match so much better with the colour both of stone and paint, that they have obtained a universal preference in London and its immediate vicinity.

At Hedgerly, a village near Windsor, red bricks, about one inch and a half thick, of a very firm texture, are made; they will stand the greatest violence of fire, and are called *Windsor bricks*, and sometimes *fire-bricks*.

Bricks for paving are of the same dimensions with Windsor bricks, viz., nine inches long, four inches and a half broad, and one inch and a half thick. Besides these, there are what are called *paving-tiles*, which are made of stronger clay, of a red colour. The largest are about twelve inches square, and one inch and a half thick; the next size, though called ten-inch tiles, are about nine inches square, and one inch and a quarter thick. *See* Tiles.

Besides the foregoing varieties, the following are worth notice, though some of them are not much in use: 1. The ordinary *Paris brick* is eight inches long, four inches broad, and two inches thick, French measure, which makes them rather larger than ours. 2. *Buttress*, or *plaster bricks*, made with a notch at one end, half the length of the brick; used for binding work built with great bricks. 3. *Capping bricks*, used for the purpose which their name denotes. 4. *Great bricks*, used in fence walls, are twelve inches long, six inches broad, and three thick. 5. *Cogging bricks*, for making the indented works under the capping of walls built with great bricks. 6. *Compass bricks*, of a circular form, for steyning wells. 7. *Concave*, or *hollow bricks*, made flat on one side, like an ordinary brick, and hollowed on the other side; used for drains and water-courses. 8. *Dutch*, or *Flemish bricks*, used in paving yards, stables, &c., also for lining soap-boilers, cisterns, and vaults. 9. *Feather-edged bricks*, made of the same size with the ordinary statute bricks, but thinner on one edge than on the other; they are used for pinning up brick panels in timber buildings.

Brick-Nogging, a wall constructed with a row of posts or quarters, disposed at three feet apart, and with brickwork, so as to fill up the intervals. This kind of walling is generally either the thickness or breadth of a brick, and the woodwork flush on both sides with the faces of the bricks. In brick-nogging, thin pieces of timber, reaching horizontally from post to post, are disposed so as to form the brickwork between every two posts or quarters, into several compartments in the height of the story; each piece being inserted between two courses of bricks, with its edges flush with the faces of the wall.

Brick and Stud. *See* Brick-Nogging.

Brick-Kiln, a building erected in the form of the frustum of a cone, for the purpose of burning bricks.

BRICKLAYER, a workman who builds with bricks. His business, in London, includes walling, tiling, and paving with bricks or tiles; some jobbing-masters also undertake plastering. Country bricklayers unite bricklaying, plastering, and not unfrequently masonry. The bricklayer's materials are bricks, tiles, mortar, laths, nails, and tile-pins; with which he is supplied while at work by a labourer, who likewise makes the mortar.

Bricklayers form a very numerous body of artisans in this country. A good workman can lay 1,500 bricks daily in walls. His wages in London are from five to six shillings a day. The immense demand for bricklayers caused by the extensive works connected with railways, and the great increase of building operations in the last few years, have enabled good workmen to command almost any amount of wages.

Bricklayers, in London, are, by a charter granted in 1568, a corporate company, consisting of a master, two wardens, twenty assistants, and seventy-eight on the livery.

BRICKLAYING, BRICKWORK, the art of building or erecting walls or edifices with bricks, cemented together with mortar, cement, &c. For the materials, &c., used in this business, see the articles Brick, Bricklayer, Mortar, Tiles, Cement, &c.

The first thing to be attended to, in bricklaying, is to dig trenches for the foundations, after which the ground must be tried with an iron crow, or rammer, to see that it is sound: if it appear to shake, it must be bored with a well-sinker's tool, in order to ascertain whether the shake be local or general. If the soil prove generally firm, the looser parts, if not very deep, may be dug up till a solid bed be got at, on which a pier or piers may be built, as hereafter described; if the ground be not very loose, it may be made good by ramming into it large stones, close packed together, or dry brick rubbish, of a breadth at the bottom proportioned to the intended insisting weight; but if the ground be very bad, it must be piled and planked, to ensure the safety of the structure.

In building upon an inclined plane, or rising ground, the foundation ought to rise with the inclination of the ground, in a series of level steps, which will ensure a firm bed for the courses, and prevent them from sliding, as they would be apt to do if built on inclined planes; and in wet seasons the moisture in the foundation would induce the inclined parts to descend towards the lowest parts, to the manifest danger of fracturing the walls, and destroying the building.

When the ground proves loose to a great depth in places over which it is intended to make windows, doors, or other apertures, while the sides on which the piers must stand are firm, it is a good practice to turn inverted arches under such intended windows, &c. Indeed, this is a necessary precaution in all cases where the depth of wall below the aperture will admit of it. For the small base of the piers will more easily penetrate the ground, than one continued base; and as the piers may be permitted to descend, in a certain degree, so long as they can be kept from spreading, they will carry the arch with them, compressing the ground, and forcing it to reaction against the sides of the inverted arch, which if closely jointed, so far from yielding, will, with the abutting

piers, operate as a solid body. Whereas, if this expedient of inverted arches be not adopted, the low piece of wall under the aperture, not having a sufficient vertical dimension, will give way by the resistance of the ground upon its base, and not only fracture the brickwork between the apertures, but also the window-sills. Hence it is evident that these arches should be turned with the greatest exactness, and should be in height at least half their width. The parabolic curve will be found most effectual in resisting the reaction of the ground; it being the form most adapted to the laws of uniform pressure.

The bed of the piers ought to be of equal solidity throughout; for though the bottom of the trench may be firm enough, yet if there be any difference in substance, the settlement will be partial, the amount thereof varying according to the softness of the ground; consequently the piers on the softer ground will settle more than those on the firmer, and occasion a vertical fracture in the superstructure.

Should the solid parts of the trench be found under the intended apertures, and the softer parts where piers are to be built, the reverse of the above practice must be resorted to, viz.: build piers on the firm ground, and suspend arches, not inverted, between them; in performing which, attention must be paid to the insisting pier, whether it will cover the arch, or not; for if the middle of the pier rest over the middle of the summit of the arch, the narrower the pier is, the greater should be the curvature of the arch of its apex. When suspended arches are used, the intrados ought to be clear, that the arch may have its full effect. Here also, as before, the ground on which the piers are erected should be of equal firmness, lest the building be injured by an unequal settling, which is attended with much more mischievous consequences than where the ground, from being uniformly soft, permits the piers to descend equally, in which case the building is seldom or never damaged.

When it is necessary to ram foundations, the stone, being previously chopped or hammer-dressed, so as to have them as little taper as possible, should be laid of a breadth proportioned to the weight intended to be rested on them, and rammed closely together with a heavy rammer. In ordinary cases, the lower bed of stones may project about a foot on each side of the wall, on which another course may be laid, so as to bring the upper bed of stones upon a general level with that of the trench, projecting about eight inches on either side of the wall, or receding four inches on each side within the lower course. Care should be taken that the joints of every upper course fall as nearly as possible upon the middle of the stones in the course immediately beneath it; a principle also to be strictly adhered to in every kind of walling; for in all the modes, various as they are, of laying stones or bricks, the uniform object is to obtain the greatest lap one upon the other.

The directions for preparing a solid foundation, refer to the general practice amongst builders before the introduction of concrete. The now almost universal use of the latter, as a certain, convenient, and ready means of obtaining a secure foundation, has rendered it necessary to give a description of the mode in which this material is generally used.

The ground having been examined as described in the first part of this article, a sufficient depth must be excavated in the bottom of the trenches, to allow of throwing in a quantity of concrete, varying in breadth and depth, according to the size and character of the building to be erected, and the necessary width of the footings.

The concrete is composed of different materials, and proportions of those materials, as the qualities of sand, lime, &c., are most conveniently obtained in the locality of the building. The concrete used in and near London is generally composed of Thames ballast and fresh burned stone-lime, (ground to powder without slacking,) in the proportions of from one-fifth to one-ninth of lime to one of the ballast. These ingredients should be well blended together dry, and as small a quantity of water added as will bring them to the consistency of mortar; and then, after turning over the materials with the shovel once or twice, thrown as quickly as possible into the foundation, from a height of several feet. It sets very quickly, so that it is desirable that the mixture should be made at, or close to the height from which it is thrown, and then spread and brought to a level as expeditiously as possible. *See* CONCRETE.

Having premised thus much on foundations, we proceed to the operation of walling; the first object in which is the due preparation of the cementing material.

Mortar is most commonly used in modern brick buildings. It is composed of lime, gray or white, but gray or stone-lime is the better, mixed with river-sand, or road-sand, in the proportion of one of gray lime to two and a half of sand, and one of white or chalk-lime to two of sand.

In slacking the lime, no more water should be used than is barely sufficient to reduce it to powder; and it should be covered with a layer of sand, in order to prevent the gas, wherein is the virtue of the lime, from flying off. It is best to slack the lime in small quantities, about a bushel at a time, in order to secure its qualities in the mortar, which would evaporate were it to remain slacked any length of time before being used. *See* MORTAR.

The mortar, when about to be used, should be beaten three or four times, and turned over with the beater, so as to incorporate the lime and sand, and break the knots that pass through the sieve: this not only renders the texture more uniform, but by admitting the air into the body and pores of the mortar, makes it much stronger. Should the mortar stand any length of time after this operation, without being used, it must be beaten again: it should be observed, that in these beatings very little water should be used; though in hot and dry weather the mortar may be kept considerably softer than in winter.

In dry weather, and for firm work, the best mortar must be used, and the bricks should be wetted, or dipped in water as they are laid; but in damp weather, the latter precaution will be unnecessary. The wetting of the bricks causes them to adhere to the mortar, which they will never do if laid dry, and covered with sand or dust, as they may be removed without the adhesion of a single particle of the mortar.

In laying the foundations of walls, the first courses are always laid broader than the wall intended to be carried up; these courses are called the *footings*, and the projections are called set-offs; there are generally two inches in each projection.

In working up the wall, not more than four or five feet of any part should be built at a time; for as all walls shrink immediately after building, the part which is first brought up will settle before the adjacent part is brought up to it; and the shrinking of the latter will consequently cause the two parts to separate. Unless it be to accommodate the carpenter, &c., no part of a wall should be carried higher than one scaffold, without having its contingent parts added to it. In carrying up any particular part, the ends should be regularly sloped off, so as to receive the bond of the adjoining parts, on the right and left.

In laying bricks, there are four kinds of BOND; viz., English-bond, Flemish-bond, Herring-bond, and Garden wall-bond. The two first are principally used in modern brickwork, the others only occasionally.

In *English-bond*, a row of bricks laid lengthwise on the length of the wall, is crossed by a row with its breadth in the said length, and so on alternately. The courses in which the lengths of the bricks are disposed through the length of the wall, are called *stretching courses*, and the bricks, *stretchers:* the courses in which the lengths of the bricks run in the thickness of the walls, are called *heading courses*, and the bricks, *headers*. The other sort of bond, called *Flemish-bond*, consists in placing a header and a stretcher alternately in the same course. *See* BOND, *English*, &c.

When new walls are to be built into old it is usual to cut a chase, or draw a brick at every other course in the old work, and *tooth* in the new work. When it is intended to add walls to buildings, these toothings are left.

The most difficult work for a bricklayer to execute is the groining or intersection of arches in vaults, where every brick has to be cut to a different bed. This and the arches called gauged arches, either circular or straight, require the neatest workmanship. Some straight arches are made roughly; that is, the bricks are inclined each way, parallel to each other, on the respective skewbacks, or shoulders of the arch, until the soffit-ends of the bricks touch, when the vacant space at top is filled with two bricks, forming a wedge: this arch, like other straight arches, is constructed on a camber slip, or piece of wood slightly curved on the upper side for centering.

In steining wells, a centre must be first made, consisting of a boarding, of inch or inch-and-a-half stuff, ledged within with three circular rings, upon which the bricks are laid, all headers. The gaps between the bricks towards the boarding are to be filled in with tile or pieces of brick. As the well-sinker excavates the ground, the centre with its load of bricks sinks, and another, similarly charged, is laid upon it, another upon that, and so on, till the well is completed; the centering remaining permanently fixed with the brickwork. This is the method generally adopted in London, at least where the soil is sandy and loose; where it is firm, centerings are not requisite. In the country, among many other methods, the following most prevails: rings of timber, without the exterior boarding, are used; upon the first ring, four or five feet of bricks are laid, then a second ring, and so on. But this is far inferior to the mode above described, as the sides of the brick-work are apt to bilge in sinking, particularly if great care be not taken in filling and ramming the sides uniformly, so as to keep the pressure regular and equal. In steining wells, and in the construction of cesspools, a rod of brick-work will require at least 4,760 bricks.

In winter, it is essential to preserve the unfinished wall, as much as possible, from the alternate effects of rain and frost, than which nothing is more destructive to a building; the rain by penetrating into the very heart of the bricks and mortar, and the frost by converting the water, so lodged, into ice, expanding its bulk, and bursting or crumbling the materials in which it is contained. The decay of buildings, commonly attributed to the effects of time, is, in reality, occasioned by this operation and counter-operation of the rain and frost, but as, in finished edifices, they have only a vertical surface to act upon, their effects are not rapidly extended. In an unfinished wall, there is a horizontal surface, by which both rain and frost find an easy access into the body of the work; care must therefore be taken to exclude them, by a sufficient covering, as soon as the frost or stormy weather sets in, either of straw, which is most usually employed, or of weather-boarding, placed in the form of a stone coping, so as to throw off the water equally on either side: but in the latter case, it is advisable to have a good body of straw under the wood, as no precaution can be too great, for the security and strength of the work.

A variety of pleasing cornices and ornaments may be formed in brickwork, by the disposition of the bricks, frequently without cutting them, or if cut, chamfering only may be used; but a great defect is frequently to be observed in these ornaments, particularly in the bilging of the arches over windows. This arises from mere carelessness in rubbing the bricks too much off, on the inside; whereas, if due care were taken to rub them exact to the gauge on the inside, that they bear upon the front edges, their geometrical bearings being united, they would all tend to one centre, and produce a well-proportioned and pleasing effect.

A rod of brickwork was taken from the original standard of $16\frac{1}{2}$ feet square, and consequently the supeficial rod contained 272.25 square feet, or $272\frac{1}{4}$ square feet; but as the quarter was found troublesome in calculation, 272 superficial feet was admitted as the standard for brickwork; the result is the same in practice, when it is considered that equal values will be found by annexing the proportional price per rod to each; and indeed, if the same price be appropriate to each, the difference would be so trifling as not to be worth the trouble of calculating. The standard thickness of a brick wall is $1\frac{1}{2}$ brick in length, therefore if 272 square feet be multiplied by $13\frac{1}{2}$ inches, the result is 306 cubic feet in the rod.

A rod of standard brickwork with mortar, will require 4,500 bricks at a medium, allowing for waste; this number will depend upon the closeness of the joints, and the size of the bricks. The mortar in a rod of brickwork will require $1\frac{1}{2}$ cwt. of chalk-lime, or one cwt. of stone-lime, and $2\frac{1}{2}$ loads of sand with stone-lime, or 2 loads with chalk-lime.

In walling, a foot of reduced brickwork will require 17 bricks. A foot superficial of marl facing laid in Flemish bond, will require 8 bricks; and a foot superficial of gauged arches, 10 bricks. In paving, a yard will require 82 paving-bricks, or 48 stock-bricks, or 144 Dutch clinkers laid on edge, or 36 bricks laid flat.

In tiling, 100 superficial feet make a square. A square will require, of plain tiles, 800 at a 6-inch gauge, 700 at a 7-inch gauge, or 600 at an 8-inch gauge. The distance of the laths will depend upon the pitch of the roof, and may require a 6, 7, or 8-inch gauge; thus, a kirb roof will require a gauge of $7\frac{1}{2}$ or 8 inches in the kirb part, and the upper part 6, $6\frac{1}{2}$, or 7 inches, the distance being less as the angle of elevation is less. A square of plain tiling will require a bundle of laths, more or less according to the pitch, two bushels of lime and one of sand, and a peck of tile-pins at least. The laths are sold in bundles, which generally consist of 3, 4, and 5-feet lengths; the 3-feet are 8 score, the 4-feet 6 score, and the 5-feet 5 score to the bundle. The nails used in lathing, are fourpenny. They are purchased by the long hundred, viz., six score to each hundred, and charged by the bricklayer by the short hundred, viz., five score to the hundred. The rates of charge by the hundred are as their names imply, viz., fourpenny, fourpence per hundred; sixpenny, sixpence per hundred. The number of nails required to a bundle of five-feet laths are 500, and to a bundle of six-feet laths 600. A square of pan-tiling will require 180 tiles, laid at a 10-inch gauge, and a bundle of laths. The bundle consists of 12 laths, 10 feet long.

In lime measure, 25 striked bushels, or 100 pecks, is a hundred of lime; 8 gallons, or $2{,}150\frac{2}{5}$ cubic inches, is a bushel of dry measure; and $268\frac{4}{5}$ cubic inches is a gallon.

In sand measure, 24 heaped bushels, or 30 striked bushels, is a load, and 24 cubic feet weigh a ton. In mortar measure, 27 cubic feet make a load, which contains half a hundred of lime, with a proportional quantity of sand; 1,134 cubic inches make a hod, which is 9 inches by 9, and 14 inches long; 2 hods of mortar make a bushel nearly.

A ton weight contains $23\frac{1}{2}$ cubic feet of sand, $17\frac{1}{3}$ of clay, or 18 of earth, or 330 bricks.

A cubic foot contains 95lb. of sand, 135lb. of clay, or 124lb. of common earth, or 125 bricks.

To measure trenches for foundations.—All kinds of excavations of earth are measured by the number of cubic yards which they contain; therefore, to find the number of cubic yards in a trench, find the solidity of the trench in cubic feet, which divide by 27, the number of cubic feet in a yard, and the quotient, if any, is the answer in cubic yards, and the remainder, if any, shows cubic feet.

Example.—The length of a trench is 62 feet, the vertical depth 2 feet 6 inches, and the breadth 2 feet 9 inches.

```
        62
         2½
       ----
       124
        31
       ----
       155
         2¾
       ----
       310
        77  6
        38  9
     ---------
27 )   426  3 ( 15 yards 21 feet, the answer.
        27
       ---
       156
       135
       ---
        21
```

In the horizontal dimensions, if the trench is wider at the top than at the bottom, as is generally the case, and equal at the ends, take half the sum of the two dimensions for a mean breadth, and if the breadth of one end of the trench exceed that of the other, so as to have two mean breadths differing from each other, take half the sum of the two added together, as a mean breadth for the whole.

Or, take a mean dimension in the middle of the length, and the middle of the height, and proceed as in the above operation.

The footing of a wall is the projecting courses of brickwork under the wall, spread out to prevent it from sinking.

To measure the footing of a wall.—Multiply the length and the height of the course together, then multiply the product by the number of half bricks in the mean breadth: divide the last product by 3, and the quotient is the answer in reduced feet.

The number of half bricks in the mean breadth will be found by adding the number of half bricks in each course together, and dividing the sum by the number of courses; or take half the sum of the half bricks in the upper and lowermost courses; but if the number of courses is odd, this trouble may be saved by taking the number of half bricks in the middle course for the mean breadth.

Also, instead of measuring the height of the footing, it is usual to allow three inches to each course in height; or multiply the number of courses by 3, which gives the height in inches.

Example.—The footing of a wall is 62 feet in length, and consists of 3 courses, the middle course of which consists of $3\frac{1}{2}$ bricks; how many feet of reduced work are in the said footing?

```
      62  0
       0  9
     -------
      46  6
           7 number of half bricks in mean breadth.
3 )  325  6
     -------
     108 ft. 6 in. of reduced brickwork.
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To find the number of rods contained in a piece of brickwork. Rule I.—If the wall be at the standard thickness, divide the area of the wall by 272, and the quotient, if any, will be the answer in rods, and the remainder, if any, in feet: but if the wall be less or more than a brick and a half in thickness, multiply the area of the wall by the number of half bricks, that is, the number of half lengths of a brick; divide the product by 3, and the wall will be reduced to the standard of $1\frac{1}{2}$ brick thick. Divide the quotient by 272, and this quotient will give the number of rods required.

Rule II.—Divide the number of cubic feet contained in the wall by 306, and the quotient, if any, will show the number of rods, and the remainder, if any, the number of cubic feet.

Rule III.—Multiply the number of cubic feet in the wall by 8; divide the product by 9, and the quotient will give the area of the wall at the standard: divide the standard area by 272, and this quotient, if any, will show the number of rods; the remainder, if any, is the reduced feet. The reason of this rule may be thus shown: $\frac{8}{9\times272}=\frac{1}{9\times34}=\frac{1}{306}$ which is a divisor of a rod, without any regard to the standard.

Example.—The length of a wall is sixty-two feet, the height fifteen feet, and the breadth equal to the length of two bricks and a half: how many rods of brickwork are contained in the wall?

Operation by Rule I.

```
          62
          15
         ----
         310
          62
         ----
         930
           5 number of half bricks.
3 )     4650
        ------
272 )   1550 ( 5 rods 190 feet, the answer.
        1360
        ----
         190
```

Operation by Rule II.

```
          62
          15
         ----
         310
          62
         ----
         930
           1  10  6
        -----------
          38   9  0
         775
         930
        ------------
306 )   1743   9  0 ( 5 rods 213 feet, the answer.
        1530
        ----
         213
```

Operation by Rule III.

```
          62
          15
         ----
         310
          62
         ----
         930
           1  10  6
        -----------
          38   9  0
         775
         930
        -----------
        1743   9
               8
        -----------
9 )    13950   0
       -------
272 )   1550 ( 5 rods 190 feet, the answer.
        1360
        ----
         190
```

In the calculation of brickwork, where there are several walls of different thicknesses, it will be quite unnecessary to use the divisors 3 and 272, as will be hereafter shown.

In measuring walls within the districts to which the building act extends, it is customary to take the length of front walls within the building, and the length of party walls from the front to the rear faces of the building, in order to appropriate more easily the share of each proprietor; but in country houses, which stand insulated, and which have their adjoining faces of the same workmanship, either of the two pair of parallel walls may be taken the whole length of the external faces, and the dimensions of the other pair of parallel walls should be taken perpendicularly from the interior sides of the said walls, or the horizontal stretch of the interior side of either.

In measuring for workmanship only, it is customary to allow the length of each wall on the external side; or, if all the adjoining walls are of the same workmanship, to girt the whole on the outside; and consequently, if the building be a rectangle, the contents will by this means exceed the real quantity by four square pillars, each the height of the building, and in horizontal dimensions the thickness of each wall. This is a compensation for plumbing the angles; but this practice is unfair with regard to materials.

In measuring walls that are faced with bricks of a superior quality, the London surveyors measure the whole as if common work, and allow so much per rod for the facing, as the quality of the bricks and superior excellence of the work may deserve. The facing may be reckoned at two thirds of a brick.

In taking the dimensions of the brickwork in the different stories, the height of each part, as high as it goes of the same thickness, must be taken; and the contents of each part computed separately, the offsets being always below the joists, and consequently the wall the same thickness throughout, from the ceiling of one floor to the ceiling of another.

All apertures and recesses from any of the faces are to be deducted, but an allowance per foot lineal should be granted upon every right angle, whether external or internal, except that two external angles are formed by a brick in breadth, and then only one of them must be accounted for. This allowance is in consequence of plumbing the faces which constitute the said angles; but if the bricks are cut so as to form oblique angles, this allowance should be at least double.

It is customary, in almost every part of the country, in measuring for workmanship, to find the contents of the walls as if solid, without deducting the vacuities, so that upon this principle, if the apertures be ever so large, they must, at all events, be accounted as solid; and, in this instance, the proprietor would be greatly overcharged by the workman.

Again, in apertures of small breadth, the trouble in plumbing at the returns is equally the same at the same height as if ever so wide; but in case the voids are less than the lineal allowance, there would be a manifest loss to the master workman. It is much to be wished that such an allowance as above mentioned should be established, in order to do away the uncertainty of computing the quantity of walling, such as to be often above, and sometimes below the real value of workmanship.

Gauged arches are sometimes deducted and charged separately, and sometimes not; but it is the same whether they are deducted or not, as the extra price must be allowed in the former case, and the whole price allowed in the latter, which is much the more troublesome of the two. Gauged arches are at least five times the trouble of the best marl facing.

To measure the vacuity of a rectangular window.—Find the solidity that would fill the outside vacuity from the face of the wall to the reveal, or outside of the sash-frame; the solidity that would fill the vacuity from the outside of the sash-frame to the vertical plane of the extension of the back upwards; and the solidity that would fill the vacuity contained between the vertical plane of the back and the internal face of the wall; then add these three solidities together, and the sum will be the solidity that will fill the whole void; then add the allowances.

Or thus—Find the area of each of the three vacuities parallel to the face of the wall; multiply each area by each respective number of half bricks in the thickness of the wall, add the three products together; divide the sum by 3, and the quotient reduces the contents in superficial feet to the standard thickness.

In taking the dimensions of brickwork, inches are generally neglected.

Example.—Suppose the height of the outer vacuity, from the sill to the under side of the head, to be 10 feet, the breadth 4 feet 6 inches, and the thickness half a brick; the height of the middle vacuity from the sill to the under side of the wooden lintels, to be 10 feet 3 inches, the breadth 5 feet 2 inches, and the thickness also $\frac{1}{2}$ a brick, and the inside vacuity, from the floor to the under side of the said lintels, 13 feet; the mean breadth, supposing the inside to splay, to be 5 feet 6 inches, and the depth of the recess $1\frac{1}{2}$ brick: required the solidity that will fill the void.

Operation for the outside vacuity.

10
$4\frac{1}{2}$
40
5
45

Operation for the middle vacuity.

10	3	0
5	2	0
1	8	6
51	3	0
52	11	6

Operation for the inside vacuity.

13	
$5\frac{1}{2}$	
65	
6	6
71	6
3	
214	6

	ft.	in.	sec.	
	45	0	0	
	52	11	6	
	214	6	0	
3)	312	5	6	
	104	1	10	the solid that will fill the vacuity.

To calculate the price of a rod of brickwork.—This will depend upon the quality of the bricks and the goodness of the workmanship; for in building foundations and party-walls, which are commonly done with place-bricks, the bricklayer may easily lay 1,500 bricks in a day: in garden-walls, barns, and common country houses, where greater nicety is required in jointing, he may lay about 1,000 per day; and in gray-stock, or marl fronts, done with great care, he will hardly exceed 500 in a day. The expense per rod will also depend upon the articles of living, and consequently upon the times. One example, however, will be sufficient; the prices of materials and labour may be had from a Price Book. In the

following statement, the work is supposed to be a well-built gray-stock front, the rates of charge according to the present London prices for 1848.

	£.	s.	d.
To 4,500 gray-stock bricks, prime cost at 38s. per thousand	8	11	0
$1\frac{1}{2}$ cwt. lime, at 14s. per cwt	1	1	0
2 loads sand, at 5s. per load	0	10	0
$\frac{3}{4}$ of a day of a labourer to slack, chaff, &c. the mortar, 3s. 6d. per day	0	2	$7\frac{1}{2}$
Bricklayer 5 days, 5s. 6d.	1	7	6
Labourer 5 days, 3s. 6d.	0	17	6
	£12	9	$7\frac{1}{2}$
Add $1\frac{1}{2}$ per cent for scaffolding, &c.	0	3	$4\frac{1}{2}$
Add 15 per cent profit on the prime cost.	1	17	6
	£14	10	6

In making the calculation of a wall where the bricks of the facing are of a superior quality to the backing, it is proper to observe, that the number of bricks in the facing of a rod of Flemish-bond work will vary from 1,500 to 2,000, according to the size of the bricks and closeness of the joints; this number of bricks must be deducted from the whole number that would constitute a rod; and each number of bricks must be valued according to their respective qualities.

The following example will sufficiently explain the application of the foregoing rules in the measurement of the front wall of a house.

Example.—Suppose the front wall of a house to be four stories high, and the length 26 feet; the footing to consist of place-bricks in four courses, which are respectively, 5, $4\frac{1}{2}$, 4, and $3\frac{1}{2}$ bricks in breadth; the basement part of the wall to be built with gray-stocks, 11 feet in height, and 3 bricks in thickness; the parlour part of the wall to be 11 feet in height, and $2\frac{1}{2}$ bricks in thickness; the one-pair-of-stairs, or principal floor, to be 13 feet in height and 2 bricks in thickness; the chamber floor to be 10 feet in height and $1\frac{1}{2}$ brick in thickness; the three upper stories to be of gray-stock work, faced with marls; in each of the basement and entrance stories are to be two windows and a door, and three windows in each of the upper stories: the whole of the windows, as well as the doors, to be 4 feet in width; the windows in the basement to be 6 feet in height, and not recessed in the inside below the sash-frame; those in the parlour-story to be $8\frac{1}{2}$ feet in height, recessed from the inside of the room below the sash-frame, which is to be placed two feet above the surface of the floor; those in the drawing-room story to descend to the bottom, and to be in height 10 feet. The upper windows to be 6 feet 9 inches in height, and $2\frac{1}{2}$ feet above the surface of the floor, the head of the basement door to be upon a level with the windows, and the jambs $8\frac{1}{2}$ feet high. The street-door to entrance, or parlour-story, to be semicircular, and the top of the arch upon a level with the soffits of the heads of the windows; the sash-frames to be all sunk within the jambs in 4 inch reveals; likewise the under sides of the wooden lintels above the level of the soffits of the brick heads, to be recessed 3 inches upward, and the door-frames 13 inches into the jambs, and also 3 inches into the head; all the windows and doors to have rubbed and gauged arches: the arches of the windows to be 11 inches broad, and in height equal to four courses of the wall. Their mean length, or horizontal dimension, to be $4\frac{1}{2}$ feet; the soffits to be the breadth of a brick, or $4\frac{1}{2}$ inches, and the length is consequently four feet, the breadth of the windows: the arch of the door to be 9 inches broad on the face, and as much on the soffit: how much will the whole amount to, supposing the rod of place-bricks to be £12 15s., the rod of gray-stock work to be £14 10s., the extra facing of best marl stocks to be sixpence per foot superficial, the extra price of the rubbed and gauged arches 3s. per foot, and the lineal foot of angles in apertures to be a penny per foot: likewise, what will be the price of a rod, supposing the apertures not deducted, and what will be the rate if they are deducted, without making any other extra charge whatever; so that the profit of the master bricklayer shall be the same in either case?

The dimensions are generally taken with two five-feet rods, and entered in a book, ruled perpendicularly for the purpose. In brickwork it will be convenient to have three columns contiguous to each other on the left hand; the first vertical column to contain the dimensions, and to be only bounded by one vertical line on the right-hand side of the column: the dimensions of the same surface to be written one under the other, putting the like denominations in vertical rows; the number of times any work is repeated is put on the left of the upper dimension, and separated from it by a curve; the number of half bricks are to be written in the adjoining right-hand column, ruled on both sides, and in a horizontal line with either dimension.

It would answer little purpose to show the work arising by squaring the dimensions. It may be proper to observe, in order to avoid numerous repetitions of division, that the dimensions of the surfaces, in length and breadth, must be multiplied together, and the product multiplied by the number of times, if more than once repeated, and this last product again by the number of half bricks in the thickness of the work: but if the outline of the surface of the work be circular, or any figure whatever, the quantity of surface must be found by the rules for measuring that figure, and repeated the number of times, and this product by the number of half bricks in the thickness of the work, as before. These products may be found by beginning with any of the multipliers, and using any one of the remaining ones in each succeeding product until their number is exhausted; the result is to be placed in a third adjoining column on the right, in a horizontal row with either of the dimensions. The dimensions, the number of half bricks, and contents of every two surfaces, are to be separated from each other by a horizontal line. The numbers in the third column are the contents of the work reduced to a wall, half a brick thick; and consequently, any number of contents of the same species of work may be added together, and reduced to the standard by dividing the sum by 3; and if rods are required, the quotient must be divided by 272, which will save immense labour.

The following is a specimen of the Dimension Book: The lineal measures are as in the preceding description, and are supposed to be taken in order, as they succeed each other, beginning with the basement part of the building, whether of the same kind or not, in order to prevent frequent returning to the same place.

Where the same dimension is often repeated in different parts of the building, it would be unnecessary to insert the number of times they occur in every part; it is sufficient to make a memorandum of the number to be found in each place, on the waste, and then the number of times it is repeated in the whole may be inserted in the Dimension Book at last.

In each of the different stories, the same order, if possible, is repeated, that mistakes of overlooking any of the articles may be prevented.

Every other part will be sufficiently evident by inspection, and by attending to the general description in the example, except the semicircular head of doorway, the dimensions of which are set down in the same manner as the others, and the squaring is found by the rules for measuring a circle. Now the multiplier for the area of a circle reduced to duodecimals

is 9 in. 5 sec.; the dimensions are 4 feet by 2; these multiplied together give 8; this product again multiplied by 9 in. 5 sec. gives 6 ft. 3 m. 4 sec., and this repeated by 2, the number of half bricks on the exterior part of the aperture, gives 12 ft. 6 m. as the seconds are always unnoticed.

Dimension Book, with the Contents.

26 0 1 0	8½	221 0	Footing of wall with place-bricks
26 0 11 0	6	1716 0	Part of the wall opposite basement, of gray-stock brick-work
2(6 0 4 0	1	48 0	Exterior part of the apertures of the two windows
2(6 3 4 8	5	291 8	Interior part of ditto
4(18 3		73 0	External and internal quoins of windows
8 6 4 0	2	68 0	Exterior part of the aperture of doorway
8 9 4 8	4	163 4	Interior part of ditto
2(25 9		51 6	Quoins of doorway
26 0 11 0	5	1430 0	Part of the wall opposite parlour, or entrance, story
2(8 6 4 0	1	68 0	External parts of apertures of windows
2(8 9 4 8	1	81 8	Middle parts of ditto
2(10 9 4 8	3	301 0	Internal parts of ditto
4(28 0		112 0	Quoins of windows
8 6 4 0	2	68 0	External part of aperture of street-door, excluding the circular head
8 6 4 6	3	114 9	Interior part of aperture of street-door, excluding the circular head
4 0 2 0	2	12 6	Exterior part of aperture of semicircular head of street-door
4 6 2 3	3	23 10	Interior part of ditto
2(25 6		51 0	Straight quoins of doorway
26 0 13 0	4	1352 0	Part of the wall opposite the one pair, or principal story
3(10 0 4 0	1	120 0	Exterior part of the aperture of windows
3(10 3 4 8	3	430 6	Interior part of ditto
6(30 6		183 0	Quoins of windows
26 0 10 0	3	780 0	Part of the wall opposite attic story
3(6 9 4 0	1	81 0	Exterior parts of apertures
3(7 0 4 8	1	98 0	Middle parts of ditto
3(9 6 4 8		133 0	Interior parts of ditto
6(20 9		124 6	Quoins of windows

Sundry Extras.

11(4 6 0 8	33 0	Rubbed and gauged faces of arches in all the windows
4 0 2 0	5 6	Rubbed and gauged arch of doorway
11(4 0 0 4	14 8	Soffits in ditto
34 0 26 0	884 0	Marl facing, including apertures
2(8 6 4 0	68 0	Deduction of parlour windows from marl facing
3(10 0 4 0	120 0	Deduction of the one-pair windows from marl facing
3(6 9 4 0	81 0	Deduction of attic windows from marl facings
8 6 4 0	34 0	Deduction of the area of doorway from marl facing, excluding the semicircle
4 0 2 0	6 3	Deduction of the semicircular head of doorway from marl facing

The dimensions are most frequently wrought upon the waste, or upon the right-hand side of the leaf of the Dimension Book, which is very convenient, as the work may be inspected should any mistake be apprehended.

The arranging of the several kinds of work into columns, so as that each column may contain the same kind throughout, is called an abstract. This arrangement saves much trouble in the calculation, reduces the whole into a very small compass in homogeneous kinds, and prevents the confusion which would otherwise arise from the multitude of parts in a complex building.

The following is an abstract of the whole: The contents are placed in vertical columns, which are in number equal to the number of kinds of work, every number of the same kind being arranged in the same column. The order of each kind or species of work is the same as they occur in the Dimension Book; for example, 221 footing of walls, with place-bricks, first occurs; this is entered in the first column of the abstract: 1716, basement wall of gray-stock brick-work next occurs; these bricks and work being of a different quality, are entered in the second column of the abstract: 48, the exterior part of the apertures next occurs; this is the same kind of work as the last, but as the former is a measure of both solids and voids, and this is only a part of the measure of the voids, the 48 is placed in an adjoining column. The next number is 291 .. 8; this is a deduction of the same kind, and is therefore inserted in the abstract below the 48: the next that occurs is 73 feet of quoins lineal measure; this, being different from the preceding, is entered in a fourth column. The next that occur in the Dimension Book, are 68 and 163 .. 4, external and internal parts of the aperture of doorway; being voids of the same kind as the preceding, they are successively entered in the third column, below the 291 .. 8. The next that occurs is 51 .. 6, quoins of doorway, and is entered in the fourth column. The next that occurs is 1430 .. 0, the part of the wall opposite parlour, or entrance-story; now, though this is gray-stock work, faced with marles, it is taken only as a gray-stock wall, and is therefore entered in the second column; the difference of price for the superior quality of bricks and work being afterwards made up by affixing an extra price to the superficial contents of this part of the wall, and thus for all that follows. The whole being inserted, each column is added together, and in the quality of the brick-work the sum of the voids is taken

from the whole; the remainder is divided by 3, which gives the superficial contents in feet of the surface of a wall reduced to $1\frac{1}{2}$ brick in thickness; the deductions being negative quantities, no further notice is taken of them; the sums of the other columns being positive, the price is affixed to each common measure, whether a foot or a rod, &c., and the value of each quantity is found by this common measure; then the quantities, with the prices of their common measures and values, are inserted in a bill; the whole being reduced into a sum, gives the amount of the whole money for the wall.

Abstract.

Footing of wall of place-bricks.	The whole of the walling reduced to ½ a brick thick, taken as gray-stock work without regard to the facing. Contents of the wall.	Deductions.	Quoins of apertures by the lineal foot.
3)221 0	1716 0	48 0	
73 8	1430 0	291 8	73 0
	1352 0	68 0	51 6
	780 0	163 4	112 0
		68 0	51 0
	5278 0	81 8	183 0
	2103 3	301 0	124 6
		68 0	
	3)3174 9	114 9	595 0
		12 6	
	272)1058(3 R.	23 10	
	816	120 0	
		430 6	
	242	81 0	
		98 0	
		133 0	
		2103 3	

Rubbed and gauged arches. ft. in.	Marl facing in superficial feet. Contents. ft. in.	Deductions. ft. in.
37 1	884 0	68 0
16 6	309 3	120 0
		81 0
53 7	57 9	34 0
		6 3
		309 3

The next thing to be done is to affix the price of the common measure to each of the above species of work, and from this, to calculate the quantity of each; then insert the several sums in a bill, as follows:

Bill.

Rods.	Feet.		£.	s.	d.
0	73⅞*	Superficial of place-brick work reduced to the standard at £12. 15s. per rod	3	8	5½
3	242	Superficial of gray-stock work reduced to the standard at £14. 10s. per rod	56	8	0
0	595	Feet lineal of quoins in apertures at 1d per foot	2	9	7
0	53½	Superficial of rubbed and gauged work at 3s. per foot	8	0	6
0	574¾	Superficial of marl facing at 6d per foot	14	7	4½
			£84	13	10¾

* ⅞ not noticed in the calculation.

In the foregoing admeasurement, the quoins are valued by the foot lineal, in addition, and the method of making out the contents is different from that commonly used; but though the allowance is strictly just, and the practice shorter and less liable to mistake than that in common use; that there should be nothing wanting to gratify those who may still favour the customary method, the admeasurement is here repeated in the usual way. The mark thus — signifies a deduction.

	Dimen. ft. in.	Contents. ft. in.	Th. brick	Names.
	26 0 1 0	26 0	4¼	Footing.
	26 0 11 0	286 0	3	Walling
2	6 0 4 0	— 48 0	½	Windows
2	6 3 4 8	— 58 4	2½	Ditto
	8 6 4 0	— 34 0	1	Doorway
	8 9 4 8	— 40 10	2	Ditto
	26 0 11 0	286 0	2½	Walling
2	8 6 4 0	— 68 0	½	Windows
2	8 9 4 8	— 81 8	½	Ditto
2	10 9 4 8	—100 4	1½	Ditto
	8 6 4 0	— 34 0	1	Ditto ⌓
	8 6 4 6	— 38 3	1½	Ditto ⌓
	4 0 2 0	— 6 3	1	Ditto
	4 6 2 3	— 7 11	1½	Ditto
	26 0 13 0	338 0	2	Walling
3	10 0 4 0	—120 0	½	Windows
3	10 3 4 8	—143 6	1½	Ditto
	26 0 10 0	260 0	1½	Walling
3	6 9 4 0	— 81 0	½	Windows
3	7 0 4 8	— 98 0	½	Ditto
3	9 6 4 8	—133 0	½	Ditto

The dimensions are frequently squared upon the waste on the margin of the Dimension Book; the following is a specimen:

First.	Second.
4 8 6 3 —— 28 0 1 2 —— 29 2 2 —— 58 4	8 9 4 8 —— 35 0 2 11 2 11 —— 40 10

Third.	Fourth.
8 9 4 8 —— 5 10 0 35 0 —— 40 10 0	4 8 8 9 —— 3 6 0 37 4 —— 40 10 0

The operations are wrought in various ways: as in the first and second, by aliquot parts; the third and fourth by duodecimals. These various modes serve to confirm each other. The third and fourth are the same dimension, but the factors are inverted in respect of each other.

4 2 —— 0 8 9 5 —— 0 3 4 6 0 —— 6 3 4	4 6 2 3 —— 1 1 6 9 0 —— 10 1 6 9 5 —— 4 2 7 6 7 7 1 6 —— 7 11 4 1 6

The mark thus ⌓ signifies a semicircle. The method of finding the semicircular area is shown in the two examples above; first by multiplying the dimensions together, and multiplying the product by 9 inches and 5 seconds, as above, or by calling the feet inches, as in the first operation, and multiplying by 9 feet 5 inches.

The above contents are abstracted by inserting each area in a separate column, according to the number of half bricks it is thick.

In the following abstract, the several parts of each column are collected: the sum or amount is multiplied by the number of half bricks, and the product divided by 3; then the positive quantities are added together, and the negative ones added together, their difference is the real quantity in reduced feet, by dividing which by 272, the answer will be obtained in rods.

Wall, including Apertures.					Deductions from Wall.				
4½ bricks.	3 bricks.	2½ bricks.	2 bricks.	1½ brick.	2½ bricks.	2 bricks.	1½ brick.	1 brick.	½ brick.
Footing of place bricks.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
	286 0	286 0	338 0	260 0	58 4	40 10	100 4	34 0	48 0
ft. in.	6	5	4	450 8	5	4	38 3	34 0	68 0
26 0				476 8			7 11	6 3	81 8
8½	3)1716 0	3)1430 0	3)1352 0	572 0	3)291 8	3)163 4	143 6		120 0
							97 2	74 3	81 0
208 0	572 0	476 8	450 8	1759 4	97 2	54 5	54 5	2	98 0
13 0				700 11			49 6		133 0
							209 10	3) 148 6	
3)221 0				272) 1058 5 (3 rds.					629 8
				816			700 11	49 6	1
73 8									
				242 feet.					3) 629 8
									209 10

Instead of dividing by 3, as in the above abstract, it would be easier to add the products of the half brickwork, both for the walling and for the deductions, and subtract the deductions from the walling; divide the difference by 3, and the quotient by 272, should it be found necessary.

Wall, including Apertures.					Deductions from Wall.				
4½ bricks.	3 bricks.	2½ bricks.	2 bricks.	1½ brick.	2½ bricks.	2 bricks.	1½ brick.	1 brick.	½ brick.
ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
26 0	286 0	286 0	338 0	260 0	58 4	10 10	100 4	34 0	48 0
8½	6	5	4	3	5	4	38 3	34 0	68 0
							7 11	6 3	81 8
208 0	1716 0	1430 0	1352 0	780 0	291 8	163 4	143 6		120 0
13 0				1352 0				74 3	81 0
				1430 0			290 0	2	98 0
221 0				1716 0			3		133 0
								148 6	
				5278 0			870 0		629 8
				2103 2			291 8		1
							163 4		
				3) 3174 10			148 6		629 8
							629 8		
				272) 1058 3(3 rods 242 feet					
				816			2103 2		
				242					

The other parts of the above abstracts are as in the preceding, and are, therefore, not again repeated.

A wall common to two houses, the properties of different persons, is termed a *party wall;* but if a building stands insulated, the walls which join the entrance to the rear front are called *flank walls.* Chimneys are generally carried up, either in party walls, flank walls, or partition walls, and sometimes in all of them; but never, or very seldom, in the front or rear walls. When the walls which contain the chimneys are thin, it becomes necessary to form a projection of sufficient breadth and depth, for the reception of the flues, or as many of them as can be collected into one stack. This projection is generally a rectangular prism, showing three vertical sides, and is termed *the chimney-breast,* or *breast of the chimney.*

The method of measuring the solid contents of every part of a building, is to reduce all the parts into rectangular prisms, and then find the solid contents of each prism. It frequently happens that walls consist of a cluster of prisms, which may be differently divided, in order to separate them. All apertures or cavities of any consequence, ought to be deducted from the measure, whether the proprietor or the contractor find the materials; but as every return or termination requires more trouble than a continued wall, an allowance ought to be made in lineal measure, upon every foot of angles, or terminations, as before mentioned, for the trouble of plumbing, levelling, and straighting. It is true, that a great length of wall requires several intermediate plumbings, but then, as they are only regulated upon the face, the trouble is small in comparison to what is required in a vertical termination, or a deflection of the wall from its course, by another return wall at an angle with it; and as these plumbings may be made at regular distances, the parts of the wall may be said to be uniformly built, and the same in all equal lengths of walls, and the time proportional to the quantity under the same circumstances of height and thickness, and therefore the area or solidity is a fair ratio of the price: and farther it is evident, that the greater the number of apertures or vacuities, in the same length of wall, the more trouble will they occasion the workmen, since more time is required to form the sides of the apertures, or the boundaries of the vacuities. In this case, therefore, the time of completing a wall of given dimensions, even with the same quality of work, depends upon the number of quoins that are to be built, and consequently cannot be determined by the solidity of the wall, but jointly by this measure and the lineal quantity of angles; for the solidity is not as the time, when the number of quoins are increased, and consequently the price not as the time; but the price may be made up by the increase of the angles.

It is likewise evident, that in building quoins, while the workmen continue at the same rate of work, the lineal quantity is in the same ratio as the time, and therefore this lineal measure is a fair representation of the value of the work. In carrying up a wall of the same horizontal length, where there are no vacuities, the quantity of work performed by the same number of bricklayers is equal in equal times, but the work requires an additional number of labourers as the height increases, to supply the materials: in this case also, the quantity of surface is a fair representation of the value of the work, in respect of the bricklayers, but an additional sum must be added as the work proceeds, and this increase would be the terms of an arithmetical progression; for suppose the materials at the foot of the scaffold, and the scaffolding erected at regular heights; now it is evident, that whatever time the labourer requires to mount the first scaffold, he would require a time double, triple, quadruple, the first, &c., to mount the second, third, fourth scaffold, &c.: the sum of all these times is the whole time. There should also be a uniform increase of price for the use of scaffolding, as well as for an additional number of labourers, as the work is carried upwards. From the aggregate of these circumstances, it is evident, that the value of the labour, with respect to the bricklayers, may be fairly estimated by the quantity of surface, of equal thickness, but an increase of price must be allowed for labourers and scaffolding.

To measure and value party walls, flank walls, and partition walls with flues.—Find the cubical contents of the whole, or each part of the wall, in feet, according to its figure, or the figures into which it may be resolved; deduct the vacuities, multiply the remainder by 8, and divide the product by 9, and the work will be reduced to the standard; then take the lineal measure of all the quoins, whether external or internal, the proper rate being affixed to each common measure, and it will give the value of the whole.

In measuring walls containing chimneys, it is not customary to deduct the flues; but this practice with regard to the materials, is unjust, though perhaps, by taking the labour and materials together, the overcharge, with respect to the quantity of bricks and mortar, may, in some degree, compensate for the loss of time; on the other hand, should the proprietor find the materials, it is not customary to allow for the trouble of forming the flues, which is therefore a loss to the contractor, or to the workman who engages to execute his part by measure or task-work.

With regard to the allowance for the lineal measure of quoins, we regret to observe, that the practice is not general, and, so far as we know, has only as yet taken place in outside and inside splays, and the angles of groins: we admit that every innovation, not founded upon reason, ought to be resisted; but as we are convinced of the justice of this mode, we have here ventured to introduce this as a general practice, which ought to be followed in every case, whether the quoins be vertical, or horizontal, or curved; and an appropriate price should be affixed to each species of quoins, whether external or internal, right-angled or oblique, curves or right lines, as the trouble is greater in external than in internal angles, greater in oblique than in right angles, greater in curved quoins than in straight ones, and still greater in groins, where the angles are continually varying, than in curves where the angles are the same throughout.

If the brick-work of the footing of a wall project equally on each side, and if the bricks be of the same kind as the wall above, take the height of the wall from the bottom of the footing, as high as it goes of the same thickness; multiply that by the length and the thickness, and reserve this solidity; then multiply the length of the wall, the height of the footing, and its projection with the addition of half a brick, will give the solidity of the footing; add these two solidities together, and the sum will be the solidity of the wall, from which deduct the vacuities, and the remainder will be the quantity of solid work.

If the breast of a chimney project from the surface of the wall, and be parallel thereto, the best method is to take the horizontal and vertical dimension of the face, multiply these together, and the product by the thickness taken in the thinnest part, taking no notice of the breast of the chimney; then find the solidity of the breast itself; add these solidities together, and the sum will give the solidity of the wall, including the vacuities, which must be deducted for the real solidity; after taking the dimensions for the quantity of brick-work, the lineal quantity of angles should be taken, and entered in the Dimension Book.

Nothing more is necessary to be said of the shaft, than to take its dimension in height, and horizontally in breadth and thickness, in order to ascertain the solidity; and then take the lineal quantity of angles, and enter them all in the Dimension Book.

If a chimney is placed in the angle, with the face of the breast intersecting the two sides of the wall, the breast of the chimney must be considered as a triangular prism; to find the solidity, therefore, multiply the area of the base by the height of the surface of the front or breast, and the product is the solidity.

To take the dimensions: from the intersections of the front of the breast into the two adjacent walls, draw two lines on the floor parallel to each adjacent wall, then will the triangle on the floor, included between the front and these lines, be equal to the triangular base of the chimney. In order to obtain the area of the triangular base, the dimensions may be taken in three various ways, almost equally easy; but as convenient a method is to take the extent of the base, which is the horizontal dimension of the breast, and multiply that by half the perpendicular; or, multiply the whole perpendicular by half the base, for the area of the surface on which the prism stands; but as fractions arise by the halving of odd numbers, it would be better in such cases to multiply the whole perpendicular by the whole base, and half the product will give the area of the prismatic base, which is that of the chimney-breast.

Sometimes the front of the chimney-breast does not intersect the walls, but is projected out from each adjacent wall by two returning vertical planes of equal breadth, each at a right angle with the adjacent wall: in this case the triangular prism is measured as before; but as the part between the prism and the wall is frequently constructed with burrs, an inferior kind of brick, this part will then consist of two rectangular prisms, and there is nothing more to do than to measure them as such; then deducting the vacuity of the fire-place from the triangular prism, the remainder will be the true solidity of this prism. In the former case, when the plane of the breast intersects the two sides of the room, a lineal allowance per foot ought to be made for the inside splays, and in the latter case, where the plane of the breast does not intersect the adjacent walls, there will be two outside splays, and two internal right angles; in this case, there must be an allowance for outside splays, and the internal right angles, per foot, running each according to its respective qualities: and in both cases it would only be fair to allow for the vertical extent of the angles of the fire-place. It is not here meant that these allowances should be made according to the present prices, which are adapted so as to include hinderances at a hazard, without any foundation to common reason, but that the

price per rod should be reduced in an adequate degree, and each kind valued by its common measure, in proportion to the time it requires to perform a given portion.

A row of plain tiles laid edge to edge, with their broad surfaces parallel to the termination of a wall, so as to project over the wall at right angles to the vertical surface, is called *single plain tile creasing*, and if two rows are laid one above the other, the one row breaking the joints of the other, then these two rows are called *double plain tile creasing;* over the plain tile creasing a row of bricks are on edge, with their length in the thickness of the wall, called a *barge course*, or *cope.*

In gables which terminate with plain tile creasing, coped with brick, in order to form the sloping bed for the *tile creasing*, the bricks must be cut, which is a considerable trouble; the sloping of the bricks thus, is called *cut splay.* Plain tile creasing and cut splay are charged by the foot run, and sometimes the latter by the foot superficial.

A brick wall made in panels between quarters, is called brick-nogging. This kind of work is generally measured by the yard square, with the quarters and nogging pieces included in the measure; but the apertures should be deducted, and the lineal measure of the angles allowed.

Pointing is the filling up of the joints of the bricks on the face, after the wall is built, with mortar, so as to be regular. Pointing is of two kinds. In either, the mortar in the joints is well raked out, and filled again with blue mortar: in the one kind, the courses are simply marked with the edge of a trowel; in this state it is called *flat joint pointing.* If, in addition to flat joint pointing, plaster be inserted in the joint with a regular projection, and neatly pared to a parallel breadth, this state is called *tuck pointing*, or *tuck-joint pointing*, formerly *tuck and patt.*

Pointing is measured by the foot superficial, including in the price, mortar, labour, and scaffolding.

Rubbed and gauged work is set either in putty or mortar, and is measured either by the foot run, or by the foot superficial, according to the construction.

The circular parts of drains may be either reduced to the standard, or to the cubic foot, and the number of rods taken if required. The mean dimension of the arch will be found by taking the half sum of the exterior and interior circumferences; but perhaps it might be proper to make the price of the common measure, whether it be a foot, or a yard, or a rod, greater, as the diameter is less; but as the reciprocal ratio would increase the price in small diameters too much, perhaps prices at certain diameters would be a sufficient regulation.

Circular walls are measured in the same way, by finding a mean girt, which is to be multiplied by the height and thickness; but all work should be valued in proportion to the time required to perform a given portion of it, but in equal portions of straight and curved walls of the same kind of workmanship, the curved portion will require a greater price than the straight portion.

In measuring canted bows, the sides are measured as continued straight walls, but the angles on the exterior side of the building, whether they are external or internal, are allowed for in addition, and paid for under the denomination of *run of bird's-mouth;* all angles within the building, if oblique, from whatever cause they are formed, whether by straight or circular bows, or the splays of windows, are allowed for, under the denomination of *run of cut splay.* These allowances are certainly what ought in justice to be, and this is fulfilling, in part, what has been so much insisted upon; but allowances should extend to right angles also: if the bricks be made to the splay, then the charge need not be greater than when the angles are right.

Brick cornices are charged by the foot run, but as there are many kinds, and these executed with more or less difficulty, the price will depend on this, and also upon the value of the materials.

Garden walls are measured the same as other walls, but if they are interrupted with piers, the thin part may be measured as in common walling, and the piers by themselves, and the additional allowance for the right angles, at per foot run, should be granted. The coping is measured by itself, according to its kind.

The common measure for tiling, is a square of 10 feet, each side containing an area of 100 superficial feet. Not only the price of new work is valued by this measure, but also stripping and re-tiling of old roofs; but if any quantity of new tiles are used, they are charged separately, and the superficial quantity of old tiles that would fill the places of the new, are computed, and deducted from the old. In plain tiling, as the rafters are generally made three-quarters of the breadth of the building, the surface of the roof is exactly equal to the area, and a half more, of the length and breadth of the building, or the space contained between the sides of the covering and ends. This being kept in view, will save much trouble in calculation.

Paving is laid either with bricks or tiles, and is measured by the yard square. The price per yard will depend on whether the bricks are laid flat or on edge, or whether laid with bricks or tiles, or of what size tiles, or whether any of these be laid in sand or in mortar.

The mensuration of groins and vaults will be shown under their respective heads.

That this work may be generally useful, we shall here subjoin the customs of several other parts of the United Kingdom, as well as the foregoing, which are calculated for London and its neighbourhood, or work done in the country by London masters.

In most counties, brick walls are measured by the yard, without reducing the thickness of the work to the standard, and fixing a price per yard according to the thickness.

In Cumberland, walls are mostly measured by the yard, and rated according to the thickness of the work: they have also a standard thickness of 18 inches, and their rod or rood is 49 square yards; these are also used by masons in the country, but neither the standard nor the rod are frequently used; apertures are always included for workmanship. In measuring the breasts of chimneys, they take the horizontal girt from wall to wall, to this they add the number of withs, or divisions between the flues, reckoning each with 3 inches, for the whole breadth; the height of the story, or as high as the work goes on uniformly, is the other dimension of the face, and the thickness is reckoned 9-inch work. In measuring a chimney-shaft, they girt it all round, then add the number of withs for the breadth, as before, and if there is only one row of flues, they reckon the thickness a 9-inch wall.

In Scotland, the brickwork of outside walls is generally measured by the rood of 36 square feet, and this measure is almost, if not quite, general. In Glasgow, the standard thickness is 14 inches, or $1\frac{1}{2}$ brick, the same as London; and walls of less thickness are generally measured by the yard, and the rate of price is according to the thickness of the work. Chimney shafts, or stalks as they are there called, are girt about for their horizontal dimension, and the altitude of the shaft, together with half its thickness, is the other dimension of the face; and the thickness is reckoned a brick and a half. In measuring the breasts of chimneys, they take the breadth of the face, and one return for the length, and the other dimension of the face is the height as far as the

work goes of a uniform quality and thickness; the thickness is what the breast really projects. Vacuities for doors and windows are not deducted from outside work.

In Ireland, the common measure is a perch of 21 square feet, being 21 feet long, and 1 foot high; the standard thickness is 9 inches only. The custom there, as also in most country places in Great Britain, was to include the openings. A 4-inch wall is reckoned two-thirds of a 9-inch wall; and a 3-inch wall, half a 9-inch wall. In the centering of sewer vaulting, half the arch is allowed; and in groin vaulting, the whole arches are done at so much per piece, according to their kind; splayed jambs, cant quoins, &c., by the running foot.

For further information on measuring, the reader is referred to a valuable little work, called "The Student's Guide to the Practice of Measuring and Valuing Artificers' Works," published by *Weale*, *London*.

Materials in bricklaying are charged as follows:—

Fine bricks, red rubbers, best marl stocks for cutters, second best, pickings, common bricks, place bricks, paving bricks, kiln-burnt bricks, and Dutch clinkers, by the thousand.

Red rubbers, kiln-burnt bricks, and fire-bricks, are also sold by the hundred.

Foot-tiles and ten-inch tiles, either by the hundred or thousand.

Sunk foot-tiles, and ten-inch tiles, with five holes, by the piece.

Pantiles, plain tiles, and nine-inch tiles, by the thousand.

Oven-tiles, Welch oven-tiles, Welch fire-lumps, fire-bricks, and chimney-pots, are sold by the piece.

Sand, clay, and loam, by the load: lime sometimes by the hundredweight.

Dutch terras, Parker's Roman cement, and lime, by the bushel.

Pantile laths, oak laths, double and single, for slating, are sold by the bundle or load.

Hair and mortar by the load.

Mortar, lime, and hair fine stuff, Parker's cement, and blue pointing mortar, are sold by the hod. Hair is sometimes sold by the bushel.

Hip hooks and T nails by the piece.

In the former edition of this work was inserted a number of tables, showing the prices and quantities of materials; but as there are now published several useful *price-books*, in which this kind of information is given, it has been considered better to refer to them than occupy so large a portion of our limited space as the tables would necessarily occupy.

BRIDGE, a structure of wood, stone, brick, iron, or other material, raised over a river, pond, lake, or any intervening space, for the purpose of affording a convenient mode of passage for men or animals. The extreme supports of a bridge are called the *butments*, or *abutments*. *See* Abutment. If composed of more than one opening, the intermediate supporters are called *piers*: the protecting walls or fences on each side are called *parapets*.

When the bridge is intended for both foot-passengers and carriages, the sides are generally raised, and sometimes paved with flag-stones, and are called *banquettes*, or *foot-paths*; the middle part, being reserved for carriages, is the *road*, or *carriage-way*.

In this place we propose to give a slight historical sketch of the rise, progress, and present state of bridge-building, exemplified in descriptions of the most celebrated edifices of the kind in various parts of the world. Under the respective heads of Stone Bridge, Timber Bridge, Iron Bridge, Suspension Bridge, &c., will be found the required information on each of these several branches of this important subject; and some account will be given of the theory under Stone Bridge.

The origin of bridges, there can be no doubt, takes its date very far back in the annals of the human race, though we have no documents by which to trace their progressive improvement, from the trunk of a tree, rudely thrown by accident or choice over a stream, to the convenient and stupendous edifices of more modern times.

It is probable that the first bridges were composed of lintels of wood or stone, stretching from bank to bank; or if the breadth of the river or valley to be passed were considerable, resting on piers or posts fixed in the bed of the river. In a strong current, the frequent piers or posts required for the support of lintels, would, by contracting the water-way, increase it to a torrent, obstructive of navigation, and ruinous to the piers themselves. In constructing bridges therefore over rapid rivers, it would be found essential to their stability, that the openings between the supporters should be as wide as possible, and every facility given to the free passage of the water; and as this could be effected only by the use of stone arches or wood trusses, there can be no doubt that these inventions were perfected before bridges of importance had become common.

There are still remaining bridges of great antiquity built by the Romans, but we are not acquainted with the earliest history of so useful a contrivance. It is by many supposed that the Greeks very soon adopted the use of *arches*, but at any rate they do not appear to have applied them to other purposes than for covering apertures in their buildings. *See* Arch, Architecture. Nor had they a bridge over the Cephisus, which crossed the high-road between Athens and Eleusis, till the Emperor Adrian erected one. In the Old Testament there is no mention of a bridge, and perhaps the bridge of Semiramis, at Babylon, may be considered the oldest on record.

The Chinese lay claim to a high antiquity for their skill in bridge-building by means of arches. Several of these structures are of great magnitude, built of stone, and turned on arches in the usual manner; others are constructed with stones from five to ten feet in length, so cut as each to form the segment of an arc, which consequently has no key-stone; ribs of wood being fitted to the convexity of the arch, and bolted through the stones by iron bars, fastened in the solid parts of the bridge.

The suspension-bridges of South America are of a very extraordinary character, and from the lightness of their materials, their oscillation, and the great height at which they are sometimes suspended, present to the startled traveller objects at once alarming and picturesque, and well calculated to try the strongest nerve. *See* Suspension-Bridge.

The Roman bridges are described by Bergier, as possessing all the requisites met with in a modern bridge; they consisted of piers, arches, butments, carriage-ways, and raised banquettes or footpaths separated from the road by a railing, and sometimes furnished with a cover to shelter passengers from the weather. Their solidity and proportion prove they must have been constructed on sound principles.

The superintendence and care of bridges was always an important object with the Romans; it was at first committed to the priests, who thence obtained the name of *pontifices*; afterwards it was given to the censors and curators of roads; and at last the emperors took it into their own hands. In the middle ages, the building of bridges was esteemed to be an act of religion; and about the close of the twelfth century, St. Benezet founded a regular order of hospitallers, under the denomination of *pontifices*, or bridge-builders, whose pro-

vince it was to erect bridges, appoint ferries, and entertain travellers in hospitals built on the banks of rivers.

Of the bridges of antiquity, that built by Trajan across the Danube, near the town of Warhel, in Hungary, is allowed to have been the most magnificent. It was destroyed by Adrian, but some of the piers may still be seen.

The remains of a bridge bearing as strong marks of ruined magnificence as any of antiquity, are to be met with at the bottom of a hill, on which the town of Narni is seated, on the road between Loretto and Rome. This bridge was built by Augustus, to join two mountains, between which flows the river Nera, and to enable the inhabitants of Narni to pass on a level from one mountain to the other. It was of an extraordinary height, and its whole length, 850 palms (637½ feet). It consisted of four large unequal arches.

The next considerable Roman work of this kind is the *Pont du Garde*, about three leagues from Nismes; which serves the double purpose of a bridge over the Gardon, and an aqueduct for supplying the people of Nismes with water. The bridge, which consists of six arches, is about 465 feet in length, and supports a second series of 11 arches, which are continued beyond the extremities of the bridge, and form a junction with the slope of the mountains on either side; it is about 780 feet long. Over these is a third series of 35 arches, much smaller than those below, 850 feet in length, supporting a canal on a level with the two mountains, along which the water is conveyed to Nismes by a continued aqueduct. This extraordinary edifice is built with very large stones, held together by iron cramps without cement. The whole height is 190 feet above the lower river.

The bridge of *St. Esprit*, near Lyons, is of Roman origin, and has long been deemed one of the finest and boldest of the ancient bridges of France. Its whole length is upwards of 800 yards; it is very crooked, bends in several places, and makes many unequal angles, particularly in those parts where the river has the strongest current. The arches run from 15 to 20 fathoms in width. The feet or bottoms of the piers consist, in their lower parts, of several courses of footings jutting out like steps; and are each protected by two pedestals, projecting from them. Between the large arches are smaller apertures, like windows, reaching nearly to the tops of the pedestals, about the middle of the pier. This mode of construction was adopted with a view to break gradually the mighty force of the Rhone: the several courses of steps, jutting out from the piers, oppose and break the stream by portions, and prevent it from operating with its whole force upon the fabric at once; and when the flood rises so high as to cover the steps and pedestals, the small arches, or windows, allow the water to pass freely, which otherwise would have choked in the upper part of the great arches, and endangered by their being forced up.

The city of Valenza de Alcantara, in Spain, is celebrated for its ancient bridge over the Tajo, or Tagus, about 25 miles from Madrid, built in the time of the Emperor Trajan; and, as appears from an inscription over one of its arches, by the people of Lusitania, who were assessed to defray the expense. It is 200 feet above the water, and though consisting of only six arches, is 670 feet in length, and 28 in breadth. At the entrance of the bridge is a small chapel dug in the rock by the pagans, who dedicated it to Trajan; but when the Christians obtained possession, they consecrated it to St. Julian.

Near the old town of Brioude, in the Lower Auvergne, or department of the Upper Loire, is a stupendous stone bridge, of one arch, the largest with which we are acquainted It is attributed to the Romans, and stretches over the whole stream of the Allier. The extremities of the arch rest on a natural rock, which occasions the spring on one side to be lower than on the other; it is formed of squared stones in two ranks; the rest of the fabric is of rubble-work. The span of the arch is 181 feet; its greatest height, from the level of the water to its intrados, 68 feet 8 inches; and the breadth of the bridge, 13 feet.

The bridge of Avignon was begun in the year 1176, and finished in 1188, probably under the direction of St. Benezet and the fraternity of hospitallers, over whom he presided; it consisted of 18 arches, and was about 1,000 yards in length. The road-way was so narrow, that two carriages could not pass each other in any part; this had caused it to be deserted by all but foot-passengers long before its destruction, which happened in 1699, by one of those violent inundations common to the Rhone. Many of the ruinous-decayed arches still remain.

The city of Venice has nearly 500 handsome bridges of one arch, and various sizes, over the canals, &c.; most of them are of white stone, similar to that with which the streets are paved, without any balusters or fence on either side. Of these the principal is the Rialto, esteemed, when erected, a master piece of art. It was begun in 1588, and finished in 1591, after a design of Michael Angelo, and consists of one bold flat arch, nearly 100 feet wide, and only 23 in height from the level of the water. Its breadth, which is 43 feet, is divided into three narrow streets, by two rows of shops: the middle street is the widest, and in the centre there is an arched aperture, by which the three streets communicate with each other. At each end of the bridge is an ascent of 56 steps, and the prospect from its summit is both lively and magnificent. The foundation extends 90 feet, and rests upon 12,000 elm piles; the whole exterior of the bridge, as well as of the shops, is of marble. The building cost the Republic 250,000 ducats.

The most stupendous and magnificent work ever executed in the department we are now speaking of, is the aqueduct bridge of Alcantara, near the city of Lisbon. It was begun in the reign of John V. king of Portugal, in the year 1713, and was finished on the sixth of August, 1732, under the superintendence of Brigadier Mansel de Maya. The aqueduct commences at a spring near Ribeira de Caranque, about three leagues and a half from Lisbon, to which city the water is conveyed for the supply of the inhabitants. The aqueduct passes subterraneously through the hills, receiving in its course the waters of several springs, and stretches across many valleys on the tops of magnificent ranges of arches, of which that crossing the vale of Alcantara is the principal. When the water emerges from its subterraneous passage, it is received in two channels on the tops of these arches, each about 12 inches deep; it generally flows at about the depth of seven inches, yielding an abundant supply for the city and its environs. The interior height of this building is 13 feet, and between the streams is a paved walk or foot-path. The subterraneous passages are continued of the same height and width throughout the whole extent of the works, and are lighted and ventilated by openings to the surface of the hills through which they pass. Over each of these openings are turrets or square towers, with strong latticed windows, to prevent mischievous persons from throwing stones, &c., into the aqueduct. These turrets are 16 in number, each 16 feet square, and rising 23 feet six inches above the roof of the aqueduct; the number of windows is 79, each three feet seven inches long, by 13 inches wide, railed with iron and latticed with bars. Beneath every second turret is an arched doorway into the aqueduct. The water-channel under the grand arch is about 24 feet in width, and seven feet in depth; but this channel is dry, except in very rainy seasons. There is, indeed, a small stream con-

stantly running through the vale of Alcantara, but it is conveyed by a very narrow channel under the pavement beneath the grand arch, and then continues its course through the valley in a stream between two and three feet wide, till it falls into the Tagus, about two miles below. This remarkable structure consists of 35 arches, of various dimensions. The eighth is the grand arch, which is 108 feet five inches in the span, and 227 feet in height: the other arches vary from 21 feet ten inches, to 72 feet in width. The total length of the piers and arches is 2,464 feet. The expense of erecting this work, and keeping it in repair, has hitherto been defrayed by the trifling rate of one rey on every pound of meat sold in the markets of Lisbon.

In France, besides the Roman structures already noticed, there are many bridges of more recent date, remarkable both for their size and the boldness of their construction: among these may be mentioned the bridge of Neuilly, built between the years 1768 and 1780, by M. Perronet. It crosses the Seine, on a line with the grand avenue of the Champs Elysées, in the front of the Tuilleries; it is level on the top, and consists of five equal arches, 120 feet French (128 feet English) in the span, with a rise of 30 French feet (32 feet English). The piers are 14 feet thick, and the bridge itself 48 feet broad. The arches, which are elliptic, are composed of 11 arcs of circles, of different diameters: the upper portion of the arch was formed with a circle of 160 feet radius, which, by its settlement during the building and after removing the centres, became flattened to an arc of a circle of 259 feet radius, differing so little from a platband, that the rise of the curve in a length of 33 feet, amounts to no more than six inches nine lines.

At Mantes is a bridge of three arches, likewise over the Seine. It was begun in 1757, by M. Hupeau, and finished by M. Perroet. The centre arch is 120 feet French (128 feet English) in the span; the side arches are each 12 feet less. The piers are 25½ feet wide, and the abutments 29 feet thick.

In the year 1771, M. Regemortes constructed a flat bridge over the river Allier, at Moulins, consisting of 13 semi-elliptical arches, of 64 feet span each, and 24 feet high.

Over the river Oise, on the great road from Paris into Flanders, is the bridge of St. Maxence, 41 feet wide, built by M. Perronet. The arches, three in number, each describe the segment of a circle, whose radius is 118 feet, leaving a water-way of 77 feet. The piers are singularly constructed; each being composed of four cylindrical pillars, nine feet in diameter, leaving between them three spaces or intercolumniations, which are arched over; those on the outsides are closed with a thin walling, and the middle one is left open.

The last foreign bridge we shall notice, is that of Orleans, over the Loire, built by M. Hupeau, between the years 1750 and 1760. It comprises nine oval arches, described from three centres, which spring at 12 inches above low water. The middle arch is 106 feet in span, with a rise of 30 feet; the extreme arches at either end, are each 98 feet wide, and 26 feet high; the intermediate arches increase gradually in dimensions as they approach the centre. The four middle piers are 19 feet wide; the others, 18 feet each; and the abutments 23½ feet thick; making the whole length of the bridge 1,100 feet.

We come now to speak of bridges in our own country, beginning with those of the greatest antiquity. The Gothic triangular bridge at Croyland, Lincolnshire, is supposed to be the most ancient structure remaining entire in the kingdom. It was erected about the year 860, but for what purpose, it is difficult, if not altogether impossible to determine; it is, however, obvious that utility was not the motive of the builder; though it may be allowed to claim the qualities of boldness of design and singularity of construction, as powerfully as any bridge in Europe. It is formed by three semi-arches, whose bases stand in the circumference of a circle, equidistant from each other, and uniting at the top. This curious *triune* formation has led many persons to imagine, that the architect intended thereby to suggest an idea of the Holy Trinity: nor is this improbable, considering the age in which it was built. The ascent on either side of the semi-arches is by steps paved with small stones, and so steep that foot-passengers only can go over the bridge. Horsemen and carriages frequently go under it, as the river is in that place but shallow. Although this structure has been built for so many centuries, the arches are still sound and free from fissures, and the building in general exhibits very trifling marks of decay.

The bridge of Burton-upon-Trent is 1,545 feet in length. It consists of 34 arches, all of free-stone, and is strong and lofty. It was erected in the 12th century, by Bernard, abbot of Burton.

Near Old Aberdeen is a celebrated Gothic bridge, over the river Don.

The centre arch of the bridge at York is 82½ feet wide, and 27 feet high.

At Winston, Yorkshire, is a bridge of a single arch, 108 feet nine inches in width, built of rubble stone, for the small cost of £500. It was designed by Sir Thomas Robinson, and built by John Johnson, a common mason, of Walsingham, in the year 1762.

At Kelso, is an elegant stone bridge over the Tweed, built by Mr. Rennie. It is quite level at the top, having five elliptical arches, each of 72 feet span; every pier has a circular projection, on which stand two Doric pilasters, supporting a simple block cornice. This bridge cost about £13,000 exclusive of the new roads at each end, which cost about £3,000 more.

Mr. Rennie also constructed the aqueduct bridge over the river Lune, at Lancaster, which is considered as one of the most magnificent works of the kind extant. At the place where it is built, the water is deep and the bottom bad: the foundations are therefore laid 20 feet below the surface of the water, on a flooring of timber resting on piles. The arches are five in number, of 70 feet span each, and rise about 39 feet above the surface of the water. It has a handsome cornice, and every part is finished in the best manner. The total height from the surface of the river, to that of the canal, is 57 feet; and the canal admits barges of 60 tons burden to navigate upon it. The foundation alone of this building cost £15,000, and the superstructure more than double that sum, although the stone was obtained from a quarry less than a mile and a half from the spot.

The bridge over the Pease, or Peaths, between Dunbar and Berwick-upon-Tweed, is rather an uncommon structure. It crosses a deep ravine, and consists of four semicircular arches. The arch on the east side of the ravine is 54 feet wide; the second 55 feet; the third 52 feet; and the fourth, or western arch, 48 feet. From the bottom of the ravine to the surface of the road, the height is 124 feet. It was designed and built by the late Mr. D. Henderson, of Edinburgh.

The bridges of Edinburgh are built, not over water, but over dry land. They are distinguished by the name of *North Bridge* and *South Bridge*, and afford an easy communication between the New Town and the royalty and suburbs on either side of it. The North Bridge, which forms the main communication between the Old and New Towns, was projected in the year 1763; but the contract for building was not signed till the 21st of August, 1765. The

architect was Mr. William Mylne, who agreed with the town-council of Edinburgh to finish the work for £10,140, and to uphold it for ten years. It was also to be finished before Martinmas, 1769; but on the 8th of August that year, when the work was nearly completed, the vaults and side walls on the south fell down. This misfortune was occasioned by the foundation having been laid upon the rubbish of the houses which had long before been built on the north side of the High-street; and which had been thrown out into the hollow to the northward; of this rubbish there was a depth of no less than eight feet between the foundation of the bridge and the solid earth. Besides this deficiency in the foundation, an immense load of earth, which had been laid over the vaults and arches, in order to raise the bridge to a proper level, had, no doubt, contributed to produce the catastrophe above-mentioned. The bridge was repaired by pulling down some parts of the side walls, and afterwards rebuilding them; strengthening them in others with chain bars; removing the quantity of earth laid upon the vaults, and supplying its place with hollow arches, &c. The whole was supported at the south end by very strong buttresses and counterforts on each side; but on the north it has only a single support. The whole length of the bridge, from High-street, in the Old Town, to Princes-street, in the New Town, is 1,125 feet; the total length of the piers and arches, is 310 feet. The width of the three great arches, is 72 feet each; of the piers, $13\frac{1}{2}$ feet; and of the small arches, each 20 feet. The height of the great arches, from the base to the top of the parapet, is 68 feet; the breadth of the bridge, within the wall over the arches, is 40 feet; and the breadth at each end, 50 feet. The South Bridge is in a line with the North Bridge, so as to make but one street, crossing the High-street almost at right angles. It consists of twenty-two arches of different sizes; but only one of them is visible, viz. the large one over the Cow-gate; and even this is small in comparison with those of the North Bridge, being no more than 30 feet wide, and 31 feet high. On the south, it terminates at the University on one hand, and the Royal Infirmary on the other.

The aqueduct bridge at Glasgow, over the river Kelvin, which conducts the great canal from the Forth to the Clyde, is the work of that great engineer, Mr. Smeaton. Its length between the abutments, or land-piers, is 245 feet; the arches, which are four in number, are each 50 feet in span, rising 15 feet 3 inches, from $15\frac{1}{4}$ feet above the footing of the piers; the three piers are each fifteen feet thick, and 54 feet high, exclusive of the footing. The extrados is a straight surface for the canal. This bridge is constructed upon true mechanical principles, and the parapet is recessed opposite to the arches in order to resist the pressure of the water in the canal. The land-piers are also ingeniously contrived to be concave outwardly, so as to spread out at the base.

The bridge at Perth was erected between the years 1766 and 1771, according to a plan by Smeaton, under the patronage of the late Earl of Kinnoul. It consists of ten arches, one of which is a land arch. The clear water-way is $589\frac{3}{4}$ feet; the extent of all the arches, $730\frac{3}{4}$ feet; and the wing-walls 176 feet: so that the total length of the bridge is $906\frac{3}{4}$ feet. The expense of building amounted to £26,446 12s. 3d., and was defrayed by public subscription. Blenheim bridge consists of three arches, the chief of which is $101\frac{1}{2}$ feet in the span.

But the most extraordinary bridge in Great Britain, is that over the Taff, near Llantrissent, in Glamorganshire, called by the Welch *Pont-y-ty-Pridd*. It is the work of William Edwards, an uneducated mason of the country, who engaged, in 1746, to erect a new bridge at this place, which for elegance of design, and neatness of execution, surpasses any thing of the kind throughout the Principality. The description and history of the progress of this bridge, we shall borrow from Mr. Malkin's *Tour in South Wales:* "It consisted of three arches, elegantly light in their construction. The hewn stones were excellently well dressed and closely jointed. It was admired by all who saw it. But this river runs through a very deep vale, that is more than usually woody, and crowded about with mountains. It is also to be considered, that many other rivers, of no mean capacity, as the Crue, the Bargoed Taff, and the Cunno, besides almost numberless brooks, that run through long, deep, and well-wooded vales or glens, fall into the Taff, in its progress. The descents into these vales from the mountains being in general very steep, the waters, in long and heavy rains, collect into these rivers with great rapidity and force, raising floods, that in their description would appear absolutely incredible to the inhabitants of open and flat countries, where the rivers are neither so precipitate in their courses, nor have hills on each side to swell them with their torrents. Such a flood unfortunately occurred soon after the completion of this undertaking, which tore up the largest trees by the roots, and carried them down the river to the bridge, where the arches were not sufficiently wide to admit of their passage: here therefore they were detained. Brush-wood, weeds, hay, straw, and whatever lay in the way of the flood, came down, and collected about the branches of the trees, that stuck fast in the arches, and choked the free current of the water. In consequence of this obstruction, a thick and strong dam was formed, and the aggregate of so many collected streams being unable to get any farther, the waters rose to a prodigious height, and by the force of their pressure carried the bridge entirely away! Edwards had given security for the stability of his bridge during the space of seven years; it had stood only about two years and a half; of course he was obliged to erect another, and he proceeded on his duty with all possible speed. The second bridge was of one arch, for the purpose of admitting freely under it whatever incumbrances the floods might bring down. The span or chord of this arch was 140 feet; its altitude 35 feet; the segment of a circle, whose diameter was 170 feet. The arch was finished, but the parapets were not yet erected, when such was the pressure of the unavoidably ponderous work over the haunches, that it sprang in the middle, and the key-stones were forced out! This was a severe blow to a man, who had hitherto met with nothing but misfortune in an enterprise which was to establish or ruin him in his profession. William Edwards, however, possessed a courage which did not easily forsake him; he engaged in it a third time, and by means of cylindrical holes through the haunches, so reduced their weight, that there was no longer any danger to be apprehended. The second bridge fell in 1751; the third, which has stood ever since, was completed in 1755." The breadth of this bridge is about 11 feet in the widest part; but in order to strengthen it horizontally, it is contracted towards the centre by seven off-sets, so that the road-way is there one foot nine inches narrower than at the extremities. It consists of a single arch, 140 feet in width, forming the segment of a circle of 175 feet; its height is 35 feet. This arch is between 40 and 50 feet wider than that of the celebrated Rialto, at Venice, and its additional altitude only in proportion. In each haunch are three cylindrical openings running quite through, from side to side, like circular windows: the diameter of the lowest is nine feet; of the middle one, six feet; and of the uppermost, three feet.

Besides the bridges already mentioned, there are other neat and elegant structures in various parts of Great

Britain and Ireland. In the latter kingdom, we cannot refrain from noticing the bridge over the Liffey, above Dublin, called *Sarah*, or *Island Bridge*, built in the year 1792, by Mr. Alexander Stevens, a mason of Edinburgh. It consists of a single elliptical arch, 106 feet wide, rising only 22 feet: and is consequently six feet wider than the Rialto, at Venice, and one foot less in altitude. The city of Dublin has likewise five other bridges over the Liffey, of which the two following are particularly worth notice: Arran, or Queen's Bridge, originally erected in the year 1684, but being destroyed by a flood in 1763, was rebuilt of hewn stone, and finished in 1768. It is built in a handsome light style, and consists of three arches, with paved *banquettes* for foot-passengers, on each side of the carriage-way, guarded with stone balusters. The other is Essex Bridge, first built in 1681, taken down in 1753, and rebuilt after the model of Westminster Bridge. It has five arches, the buttresses between which support semicircular niches, projecting from the parapet; between these niches are balustrades, which are continued to the ends of the bridge. The foot-ways are flagged, and the whole is constructed of hewn stone, in very fine taste.

We come now to those magnificent examples of bridge architecture, equalling any that the Romans have left, and surpassing all others in the world—the bridges of London. Each of these noble structures may be considered almost perfect in its kind, and as affording a specimen of the application in its grandest form, of the peculiar material of which it is constructed.

Four of these fine bridges are built of stone—namely, London Bridge, Blackfriars Bridge, Waterloo Bridge, and Westminster Bridge. They will be fully described under Stone Bridge. Southwark Bridge, built of iron, under Iron Bridge. And the beautiful new bridge lately completed at Hungerford, by Brunel, the celebrated engineer, under Suspension Bridge.

Among *Bridges of Wood*, (for the principles and methods of constructing which, see Timber Bridge,) the first that attracts our notice is the bridge of Cæsar across the Rhine. It consisted of a double row of piles, leaning to the course of the stream, and joined together at the distance of two feet from each other. Forty feet lower down the river, was another double row of piles, leaning against the stream, and towards the former row. Between the double piles, which were well rammed into the bed of the river, long beams, two feet thick, were placed, and held fast at each end by two braces. These beams being joined by transverse pieces, the whole was surmounted with hurdles. To preserve this structure from injury by the force of the water, the supporters were guarded with piles as buttresses; and above the bridge, other piles were placed, to stop the progress of trees or timber, which by accident might fall into the river, or be designedly floated down by an enemy, to destroy the work.

The bridge over the Cismone, a river falling from the mountains which separate Italy from Germany, is described by Palladio as an interesting object to the builder and architect. The river where this bridge is erected is 100 feet wide; and because the current is very rapid, and great quantities of timber are floated down it by the mountaineers, the bridge was constructed of a single span. The width is divided into six equal parts, and at the end of each part, except at the banks, which are strengthened with pilasters of stone, are placed the beams that form the breadth of the bridge. On these, leaving a little space at their ends, other beams are placed lengthwise, constituting the sides. The king-posts are disposed on either side, over both beams, connected with the projecting ends of those forming the breadth, by means of iron bolts and pins.

At Wittengen, in Switzerland, is a very curious bridge, the contrivance of Ulrick Grubenhamm, an uneducated carpenter of Tuffen, in the canton of Appenzel, celebrated for several works of the same nature. It consists of two wooden arches parallel to each other, with the roadway hanging between them. The span is 230 feet, and rises only five feet. The arches approach the catenarian shape, and are built of seven courses of solid oak logs, in lengths of 12 or 14 feet, and 16 inches and upwards in thickness. By picking these logs of a natural shape suited to the intended curve, the wood is nowhere trimmed across the grain. The logs being laid one upon the other, with their abutting joints carefully alternated, have the appearance of a wooden wall: instead of being pinned together, they are surrounded with straps of iron, at every distance of five feet, and fastened by bolts and keys. The abutments are the natural rock. The roadway intersects these arches at about the middle of their height, and is supported by cross joists, resting on a long horizontal beam, connected with the arches on either side by uprights bolted into them. Three of the spaces between these uprights have struts or braces, giving the upper work a sort of trussing in that part. The whole is covered with a roof, projecting over the arches on each side of the roadway, to defend the timbers from the injuries of the weather. This bridge is of more than sufficient strength to bear any load that can be laid upon it, though the attempt to truss the ends demonstrates that the builder was ignorant of true architectural principles.

In 1754, Grubenhamm erected another bridge, upon a plan nearly similar to the foregoing, at Schaffhausen, where the river (the Rhine) is nearly 390 feet wide. The current is very rapid at this spot, and had destroyed several stone bridges, when Grubenhamm offered to throw a wooden bridge across, of a single span; but the magistrates were alarmed at the proposition, on account of the breadth of the river, and would scarcely listen to it: at last they consented that he should build a bridge, provided he would divide it into two spans, and use the middle pier of the late stone bridge as a support at their junction. Grubenhamm complied with the wish of the magistrates so far as to divide his bridge into two unequal parts, the span of the one being 172 feet, and of the other, 193, both appearing to rest upon the old pier, though he contrived to leave it doubtful whether they really did so or not. This structure cost £8,000 sterling, and travellers inform us, that though it sustained the most heavily laden waggons in perfect security, yet the weight of a single foot-passenger caused it to tremble under him. It was destroyed by the French, when they evacuated Schaffhausen, in April, 1799.

Among wooden-bridges, the Schuylkill bridges at Philadelphia, in America, are very remarkable.

Wooden-bridges, unsupported by posts or pillars, and sustained only by butments at the ends, have obtained the denomination of *Pendent* or *Hanging Bridges*, by some also called *Philosophical Bridges*, of which Palladio has described three modes of erecting; such is the bridge over the Cismone, already described. Doctor Wallis has likewise given the design of a timber bridge, 70 feet long, without any pillars, which may be useful where supports cannot be conveniently erected; and Doctor Plott assures us, that formerly there was a large bridge over the castle ditch at Tutbury, in Staffordshire, made of short timbers, none of them above a yard in length, yet not supported from beneath, either by pillars or arches. The Spaniards use bridges of this kind for crossing the torrents of Peru, over which it would be difficult, not to say impossible, to throw more solid structures, either of wood or stone. Some of these hanging-bridges are sufficiently strong

and broad for loaded mules to pass along them with safety. In China, these flying bridges are constructed of an almost incredible magnitude; the *Philosophical Transactions* contain the figure of one, consisting of a single arch, 400 cubits long, and 500 in height.

A great change in modern bridge-building has been effected by the introduction of iron, and the use of chain or suspension-bridges. The invention of Iron Bridges is said to be exclusively English, but Duhalde gives the merit of it to the Chinese; be that as it may, there is no country where there has been so extensive an application of the discovery, or in which has been erected so many fine bridges of iron as in Great Britain. The first was set up at Colebrook Dale, Shropshire, in the year 1797, and was speedily succeeded by numerous others in all parts of the United Kingdom; for a description of which we must refer to IRON BRIDGE.

Draw Bridges are of wood or iron, sometimes of both, with stone abutments. They are placed over navigable canals and rivers, or used in fortified places for the purpose of shutting out the enemy, and are of varied construction. Some are fastened at one end by hinges, so that the other end may be raised or lowered at pleasure. The most common method of doing this is by a kind of balance, called *plyers*, in which case the bridge when drawn up stands erect, to preclude a passage across a moat, &c. Others are so constructed as to be drawn back, or thrust forward, as occasion may require. On small canals, &c., draw-bridges consist of one leaf only; but on larger navigations, wet-docks, &c., they are of two pieces, meeting in the middle, and forming an arch, which are raised or lowered by means of balance frames, movable on the tops of uprights suited in height to the magnitude of the bridge; such as that at Bristol, over the Frome. Such bridges, however, having been found inconvenient from their tackling catching the yards and rigging of vessels passing through them, a kind of bridge, diverse from all the preceding, has been invented, called a *Swivel Bridge:* these, on small rivers, are only of one frame, or leaf, and turn on a centre, or series of balls or rollers; but when made on a wider scale, they consist of two parts, one on each side of the channel, and meeting in the centre. The most complete of this kind are those constructed at the West-India and London Docks; the latter spans 40 feet, and is 15 feet wide in the road-way. It consists of cast-iron ribs, about $1\frac{1}{2}$ inch thick, turning on a number of concentric rollers, which move between two circular cast-iron rings, very nicely turned: each leaf has a flap, which lets down by a screw, and abuts upon the stone-work on either side, forming the whole bridge, when shut, into an arch capable of bearing any weight that can possibly pass over it. The whole apparatus weighs 85 tons; but it moves with so much ease, that it can be opened and shut in less than three minutes.

Suspension Bridges have only lately been introduced into this country, though known to the Chinese from a very early period. The iron-chain bridge of Yunnan is supposed to have been erected about A. D. 65, in the reign of the emperor Mingus, and is described as very similar in principle to the Hammersmith Suspension Bridge near London. In Kircher's *China Illustrata*, it is stated, that the chord-line is of the length of 200 cubits. In the *Asiatic Researches*, Turner gives a very interesting account of the singular bridges erected by the natives of Bootan. These bridges are of varied construction, but admirably adapted to the circumstances for which they are intended. Over the widest river in Bootan, there is an iron bridge, consisting of a number of iron chains, which support a matted platform; and two chains are stretched above, parallel to the sides, to support a matted border, which is absolutely necessary for the safety of the passenger, who is certainly not quite at his ease till he has landed from this swinging, unsteady footing. At another place, a bridge for foot-passengers is formed by two parallel chains, round which creepers are loosely twisted, from which planks are suspended, the end of one plank resting upon the other without being confined.

In the rude suspension bridge of South America, with its ropes of twisted bark, and its platform of cross pieces of wood interwoven in them, or the platform attached immediately to the sustaining ropes, the form assumed, the catenarian curve, is the same as in the more perfect structures of modern times—and one traces easily the transition from the simple but effective contrivance of the untutored Indian, to the master-pieces of the genius of a Telford. *See* SUSPENSION BRIDGE.

Bridges of Boats are made of boats, either of copper, tin, or wood, fastened across the stream by means of anchors or stakes, and laid over with planks. The earliest instance upon record of this kind of bridge, was that laid by Darius Hystaspes over the Ister, or Danube, in his Scythian expedition, 508 years before the Christian era. The same monarch also crossed the Thracian Bosphorus with 700,000 men by means of a bridge of boats; the strait being five stadia, or 1,008 yards in width. Modern armies carry with them tin or copper boats, called *pontoons*, to be ready on any emergency: several of them, placed side by side, across the river, till they reach the opposite shore, with planks laid upon them, form a plane for the soldiers to march on. At Beaucaire, Rouen, and Seville, are very fine stationary bridges of boats, which rise and fall with the tide: that at Rouen is nearly 300 yards long, and paved with stone, so that laden carriages and horses, as well as foot-passengers, go over it in safety. In the absence of pontoons, military bridges have been made of blown bladders, hollow casks, sheaves of rushes, &c., covered over with planks.

When bridges of this kind do not extend over the whole breadth of the river, but are contrived to float from one side to the other, they are termed *Flying* or *Floating Bridges.* A bridge of this description is generally composed of several boats connected with each other by a flooring of planks, and surrounded by a railing. This stage or raft is furnished with one or more masts, according to its dimensions, to which is fastened a strong cable, supported at proper distances by boats, and extending to an anchor, in the middle of the water, where it is made secure. The bridge thus becomes movable, like a pendulum, from one side of the river to the other, with the assistance only of a rudder. Such bridges were formerly sometimes constructed of two stories, for the more expeditious passage of a great number of men.

Another kind of flying bridge is formed of two platforms, laid one upon the other, and by means of cords and pullies the uppermost is made to run out beyond the lower platform, till its farther extremity rests against the place it was designed to reach. In the *Histoire de l'Académie Royale des Sciences*, for the year 1713, page 104, is a description of a floating bridge, which lays itself on the opposite side of a river.

Under this head we have now to describe one of the most useful and ingenious constructions of modern science and engineering skill—the steam Floating Bridge invented by Mr. J. M. Rendel, the eminent civil engineer. The first bridge on this principle was erected by Mr. Rendel across the estuary of the Dart at Dartmouth, about the year 1832, and a similar one was established about two years after, across the Hamoaze, between Torpoint and Devonport.

A very full description of the latter, accompanied by elaborate drawings, has been furnished to the Institution of Civil Engineers by Mr. Rendel himself, and from the first

volume of the "Transactions" of the Institution, we have extracted the following brief sketch.

The medium width of the river at the site of the bridge may be taken at about 2,350 feet, the strength of the current after heavy land floods is very great, and the site so much exposed, that it is not uncommon for the ships lying in the vicinity of the bridge to drag their moorings. The bridge is a large flat-bottomed vessel, of a width nearly equal to its length. The vessel is divided in the direction of its length into three parts—the middle one being appropriated to the machinery—each of the side divisions to carriages, &c. These side divisions or decks are raised about 2 feet above the line of flotation, and by means of movable platforms, an easy communication is afforded with the shore on embarking or landing. The bridge is guided by two chains, which passing through it over cast-iron wheels, are laid across the river and fastened to the opposite shores, forming as it were a road along which the vessel travels backwards and forwards.

The moving power employed is two small steam-engines turning a shaft, on each end of which is a large iron wheel whereon the guide-chains rest. The peripheries of these wheels are cast with sockets fitted to the links of the chains, so that when the bridge is put in motion by the steam-engines, it is moved in the reverse direction of, and with the same velocity as the wheels. The ends of the chains have balance-weights attached to them, which rise or fall as the tension of the chains becomes more or less.

A similar bridge has been established at Portsmouth, and plies between that place and Gosport.

Under this article we may also mention *Portable Bridges*, which are easily taken to pieces, and as readily put together again. M. Couplet speaks of a bridge of this kind, 200 feet long, carried by 40 men.

Writers on architecture have bestowed considerable attention on the subject of bridge-building, which is justly esteemed as one of the most noble and striking specimens of human art. The earliest of these is Alberti, a native of Florence, who flourished about the middle of the 15th century; he has given several judicious precepts, which, with little alteration, were afterwards laid down by Palladio, Serlio, and Scamozzi. The best of these rules are likewise given by Goldman and Baukhurst, as well as by Hawkesmoor, in his *History of London Bridge*.—M. Gautier has written a large volume on bridges, ancient and modern. M. Belidor has treated on this subject in his *Architecture Hydraulique;* as has M. Parent, in his *Essais et Recherchés Mathematiques*, vol. iii.—De la Hire, too, has touched on it, in his *Traité de Mechanique*.—Perronet has given the result of his experience in a magnificent work, which has acquired him great credit in France.—Bosset has given an excellent treatise on bridge-building, in the *Mémoires de l'Académie*.—Regemortes published, in 1771, an account of the bridge built by him over the Allier, at Moulins.—In 1760, Mr. Riou published a work entitled, *Short Principles for the Architecture of Bridges;* and Mr. Semple has given some excellent practical remarks in his *Treatise on Building in Water*, published in 1776. Other writers on the construction and principles of arches and bridges, are Muller, Labelye, Atwood, Emerson, and Dr. Hutton.

When a bridge is constructed of stone, and arched over, it requires, in the act of building, to be supported upon a mould, called a *centre;* the construction of which is shown under the article CENTRE.

BRIDGE BOARD *See* NOTCH BOARD.

BRIDGE OVER: when there are any number of parallel timbers, and another piece fixed transversely over them, then the transverse piece is said to *bridge over* the other parallel pieces. In framed roofing, the common rafters bridge over the purlins; likewise in framed flooring, the upper joists, to which the boarding is fixed, bridge over the beams or binding joists, and are therefore called *bridging joists*.

BRIDGE STONE, a stone laid from the pavement to the entrance-door of a house, over a sunk area, not supported by an arch.

BRIDGED GUTTERS, those made with boards, supported below with bearers, and covered above with lead.

BRIDGING FLOORS, those in which bridging joists are used. *See* NAKED FLOORING.

BRIDGING JOISTS, those which are sustained by transverse beams below, called *binding-joists;* also those on which the boarding for walking upon is nailed or fixed. *See* NAKED FLOORING.

BRIDGINGS, or BRIDGING PIECES. *See* STRAINING PIECES, and STRUTTING PIECES.

BRING UP, a term used by workmen for carrying up the walls to a certain height: they say, "bring up that part;" but the term *carry up* is more frequently used.

BROACH, an old English term for a spire, still in use in the north of England. The term is specifically applied to spires which spring directly from the eaves of the tower or other substructure, without the intervention of a parapet. This kind of spire is confined more especially to the earlier styles of Gothic architecture; in the later ones, the parapet is seldom dispensed with.

BROAD-STONE, the same as FREE-STONE.

BRONZE; a compound of copper and other metals, especially zinc. It is used for cannon, medals, &c.

BRONZE also denotes any piece of sculpture made of bronze metal, as statues, busts, &c., whether in imitation of the antique, or representing a modern prototype. The method of casting bronzes is described under CASTING.

BROWN, a dusky colour inclining to redness. Of this there are various shades, distinguished by different appellations, as *Spanish brown*, *sad brown*, *tawny brown*, *London brown*, and *clove brown*. *Spanish brown* is a dark dull red, of a horseflesh colour, of great use to painters, being generally used in house-painting, for priming the timber work, or first coating. The best is that of a deep colour, and free from stones. It is the best and brightest when burnt in the fire till it is red-hot. The various browns used in drawing are BISTRE, COLOGNE EARTH, and UMBER.

BRUNELLESCHI, PHILIP, the son of a notary, born at Florence in 1377, was at first designed for the bar; but not liking that profession, he was apprenticed to a goldsmith. His genius, however, turned him to the study of sculpture, geometry, and architecture. The first model by which he formed his taste in architecture was the church of St. John, at Florence, a building of good style, and much inclining to the antique; he afterwards went to Rome, to study the ancient monuments there, the best of which he measured and took drawings from; and he is said to have first distinguished the three ancient orders.

When the Florentines first thought of raising a dome upon the church of St. Mary del Fiore, they invited all the principal architects of Europe to a consultation, at which Brunelleschi proposed a double cupola, with a space between the inner and outer vaults, sufficient to admit of staircases and passages to the top. This idea was deemed so preposterous, that he was actually turned out of the assembly, for having presumed to insult the good sense and judgment of so many experienced artists, who had never heard of such a thing, and held it to be impracticable. Undaunted by this treatment, Brunelleschi persisted in maintaining the practicability

of his scheme, and demonstrated it by drawings and models: but the clamour excited by his brother artists ran so high for a time, that he was looked upon as a downright madman! At length, however, the violence of prejudice began to subside, and when it was seen that the rest of the architects produced nothing eligible for the purpose, the deputies, who had the management of the building, sent for Brunelleschi, listened candidly to what he had to propose, examined his drawings and models, and finally set him to work, under certain restrictions: they also appointed him an assistant, but his complete ignorance soon manifested itself, and he was dismissed. Brunelleschi being thus left at liberty, the citizens saw with admiration a magnificent cupola arise over their church, which Michael Angelo himself pronounced to be a masterpiece of science. This cupola is octangular, 154 cubits (Flemish) in height, on which rises a lantern of thirty-eight cubits, surmounted with a ball of four cubits, and a cross of eight cubits; making a total of 202 cubits. a height never before attempted on such a plan. Brunelleschi died before the lantern was quite finished, but he left a model, and recommended on his death-bed, that it should be loaded with the heaviest marble. The portico that was to have surrounded the tambour still remains unfinished. The peculiarity of this celebrated cupola is, that it has no counterforts.

Brunelleschi built the abbey for the regular canons at Fiesole, under the direction and patronage of Cosmo de Medicis; it is a convenient cheerful edifice, and the ornaments are in a chaste style. He also constructed several military works. A great part of the church of St. Laurence, at Florence, was built by Brunelleschi, but he died before it was completed, and his successors committed so many blunders in finishing it, that the original design is very much mutilated. The palace of Pitti, at Florence, was likewise begun from his designs; and so completely did the tide of public favour turn in his behalf, that his fellow-citizens elected him to the office of magistrate. But it was after his death that his talents were most appreciated, and his merit fully acknowledged as the reviver of pure architecture. He died in 1444, aged 67, honoured and esteemed by all who knew him, and was buried in St. Mary's cathedral.

BUCCULA, in antiquity, denotes the *umbo*, or prominent part of a shield.

BUDGET, a kind of pocket used by bricklayers, for holding nails when they lath for tiling.

BUFFET, a cabinet or cupboard for plate, glasses, or china-ware. In former times, these were frequently made very ornamental, in the form of niches, and left open in the front in order to show the furniture. The buffet is now rarely seen, except in old-fashioned houses; in modern establishments it has been superseded by the sideboard.

BUILDER, a person who contracts to build, or rear up edifices.

BUILDING, in general, is a mass formed by the junction of materials. When a building is stationary, and erected for dwelling in, or for some useful purpose or ornament, it is called an *edifice*. Those who intend to build, should make choice of an architect who is known to be a man of ability and of tried experience and integrity. The proprietor should then explain as clearly as possible his ideas and intentions respecting the proposed building, to enable the architect to furnish the requisite plans and estimates. These should be carefully examined and gone into, so that the proprietor be perfectly satisfied that his wishes are understood, and the cost of carrying them into effect brought within the extent of his means or inclinations. The whole management ought then to be committed to the architect, with full liberty in the choice of masters for the execution of the respective departments. The architect should then proceed to make out a specification, and contract for each individual branch concerned in the business, and put them into the hands of respectable tradesmen; if the estimates appear to be reasonable, the contracts should be signed. There are many kinds of work for which, however, from novelty in execution, it would be impossible to anticipate a price: but if the work consist of similar repetitions or parts, the value of one part being known, by taking an account of the time, that of the others will follow, and then the estimated expense of the whole may be ascertained. There are many proprietors whose ideas are never fixed, and no sooner is work done than it is undone: in such a case, the work should be done by measure and value, affixing a regular price to every corresponding article; and an account should be taken of the work pulled down. In whatever way the work be valued, there should be a person employed, stationary in the building, called *a clerk of the works*, whose business it is to give directions for fixing, and to superintend all parts of the execution; to keep the workmen's time, to give in weekly reports, and to examine the work, should it happen to be prepared out of the building.

The drawings necessary in the construction of an edifice are, plans of the several stories, elevations of the façades, a transverse and a longitudinal section at least, horizontal and vertical sections of all the difficult parts, and a detail of all the mouldings and ornaments at large. These ought to be committed to the care of the clerk of the works. It is not very easy for an architect to furnish all the detail before a building is to be estimated; but if time would permit this to be done, the contractors would be able to undertake the work at the lowest rate, and this would in a great measure supersede the necessity of the addition, which is too generally found necessary to cover the uncertainty of estimating large works.

With regard to building in general, it must be obvious, that to the taste, judgment, and science of the architect, must be left the selection of the character and style of the building to be erected; no certain rules can be given to form the general contour of an edifice, but the middle part ought to have some commanding feature, and the general outline of the whole should approach to a pyramidal form. Large edifices are susceptible of great splendour, by an agreeable variety of parts; but the beauty of a small building consists in the simplicity and symmetry of its surfaces.

The regularly repeated columns, entablatures, and other ornaments which may adorn a circular building, create the most pleasing feelings, and in a straight building also, the uniformity and succession of parts are usually delightful to the observer, hence the gratifying sensation arising from long ranges of colonnades, as in the Grecian temples and the aisles of churches: but the preceding observation, with respect to the entablature, does not apply in a straight building. The entablatures may either be broken or continued, according to the use of the columns; the outline of the building being still preserved in either case: for when the repetitions are fac-similes of each other, the eye will judge of the figure of the building the same, whether the entablature be continued or interrupted, which is not the case in rotund edifices. When columns are placed so remote from each other, as not to be capable of supporting an entablature, or not sufficiently near to excite the idea, the entablatures may be broken, as in the triumphal arches at Rome, where the columns are introduced to support the ornaments of triumph. In the peribolus of the Grecian temples, the broken entablatures are not only beautiful, but the repetition of the order itself

is useful in reinforcing the strength of the enclosure, and thus performing the office of buttresses to the walls. Much of the agreeable sensation in viewing our venerable antique-modern churches, arises from the uniform succession of the buttresses and their ornaments.

For farther particulars, with regard to the exterior of a building, we must refer the reader to the term BREAK.

With regard to situation, a building should be placed in a salubrious and mild atmosphere, free from noxious exhalations, within the reach of the rays of the sun, so as to make it cheerful, and to have a plentiful supply of water and coal, as likewise of all other necessaries of life: it should be surrounded with an agreeable variety of woods and walks, and ought to have an easy access to the highway. The situation should be commanding, but not so high as to expose the building to the fury of heavy winds.

With regard to the plan of a building, the disposition of the apartments must be agreeable to the intention of the design, and in general the rooms ought to be all entered by one common passage; for farther particulars on this head, see APARTMENT, CHIMNEY, PASSAGE, ROOF, ROOM, and STAIRCASE.

The modern method of placing a bedchamber and dressing-room together, each with its separate door to the common passage, and likewise with a door common to each other, is very convenient. The mode of uniting, when necessary, two or more rooms by means of folding-doors, is a very great improvement, particularly in small houses. The hall, or entrance, should at least have one chimney, and if connected with the staircase or a lofty saloon, the heat will be of essential service in warming the whole house. Double doors are useful in preserving a uniform temperature.

Besides double external doors, for the exclusion of cold winds, double windows should be used for winter apartments.

The proper distribution of rooms must be regulated by the course of the sun, in order to avoid the extremes of the summer's heat and winter's cold. Bedchambers are properly situated towards the east, in order to regulate the time of rising. Every house ought to have two sitting-rooms, to accommodate the extreme seasons of the year; that for the summer ought to be disposed in the north, and that for the winter in the south. Drawing-rooms and dining-parlours are best situated in the west, as they are generally used in the afternoon, that the declining sun may throw an agreeable shade upon objects; these matters, however, frequently depend upon other circumstances of convenience.

The drawing-rooms should be so disposed, as to be easily converted into one room, by throwing open the folding-doors. In country mansions, the kitchen should be as near the dining-room as convenient, but so disposed with regard to the passage of communication, as to prevent the effluvia from escaping to other principal parts of the house. The offices connected with the kitchen should be generally placed towards the north; but in town-houses this cannot always be done, and therefore regard must be had to circumstances. The larder, however, must always be placed beyond the influence of the heat of the kitchen. Galleries for paintings, and museums, that require a steady light, should have a northern aspect.

Windows ought to be made vertically one above the other, and not too near the angles of the building; and in large edifices, where the walls are thick, their jambs ought to be splayed or beveled, for a more full distribution of light. Lofty windows, descending to the floor, or nearly so, with a projecting balcony in front of the building, defended by a railing of cast-iron, are both healthy and agreeable. Sky-lights, in cold climates like ours, are productive of many inconveniences, as they admit of cold air, damps, rain, and snow, and thereby waste the heat generated in the house. They ought therefore never to be admitted, except for stairs and halls; but when this admission is necessary, their apertures should be of sufficient dimensions, not to hinder the passage of the sun's rays.

The plans of buildings may be of various forms; the circle is the most capacious of all figures, under the same perimeter, and a building erected upon a circular plan, is also the most strong, durable, and beautiful of all others; but its compartments are not convenient in dwelling-houses, on account of a waste of room occasioned by the disposition of angular furniture; so that the loss in this respect more than counterbalances the quantity of area gained by the property of its figure. Circular buildings are also the most expensive, and, on account of the impossibility of dividing them into compartments without distortion, they are unfit for the purpose of private edifices: on this account they were employed by the ancients only in their temples and amphitheatres, which had no need of compartition. In modern mansions, entire cylindric or polygonal buildings are seldom or never used, except in parts which form single apartments upon a floor, as in towers or bows. Though very beautiful forms of edifices may be reared upon rectilineal plans, a judicious arrangement of apartments formed both of plane and curved surfaces will make a most agreeable variety.

Of all buildings upon plans of equilateral and equi-angular polygons, the triangle contains the least area, and on account of the acuteness of its angles, rectangular furniture cannot be disposed on its area without very considerable waste; the employment of this figure, therefore, occasions not only a loss of surface from its property, but a loss also in placing of furniture: it may, however, be observed, in buildings erected upon equilateral and equi-angular polygons, the greater the number of sides the plan has, the less loss of area will be sustained on account of the property of the figure; but those with obtuse angles will still have the same objections on account of the furniture. Various figures may be adopted occasionally, for the sake of variety, when the loss of room is not an object; but for general use, the rectangular disposition of an edifice is the most convenient, as it will compart *ad infinitum* into rectangular figures, which is the best form of furniture for general use.

The accessories of a building are ornaments borrowed from sculpture and painting; but wherever they are introduced, they ought to be in character, and to indicate in some measure its destination. Figures representing animals are of a higher class than those of foliage or vegetables: the former were generally employed by the Greeks, particularly in the principal parts of their edifices, though sometimes the small parts were covered with foliage, in which the honeysuckle was most predominant. The Romans, whose taste was inferior to that of the Greeks, indulged in both. It is to the remains of the edifices of these two nations, that the architect must have recourse for the embellishments of the fabric.

Of all the ornaments applicable to buildings, columns are the most splendid and dignified, and no invention has yet been able to supplant the three Grecian orders, though a lapse of more than two thousand years has past. Pilasters are not only very beautiful, but when wrought in with the work, they reinforce the strength of the walls, and consequently the whole fabric; but they have neither the dignity nor the graceful appearance of columns.

The materials used in the construction of edifices are of various kinds, as timber, earth, mortar, chalk, stone, marble, iron, &c.; every place adopts, in the general construction of its

buildings, those materials which are its own native productions, or those of other places which can be procured by an easy carriage.

The chief writers on building, whose works have been transmitted to our hands, are Vitruvius, Alberti, Serlio, Scammozzi, Vignola, Palladio, Baldus, Barbarus, Blondel, Catanei, Demoniosius, Friard, Goldman, Perrault, Rivius, Gulielmus, Langley, Ware, and some living authors. *See* ARCHITECTURE and HOUSE.

BUILDING, in masonry, is the art of joining stones together, with or without cement, so as to form the whole or part of an edifice. Building also signifies the mass of body formed by the junction of stone with regular surfaces. In this sense it is the same with masonry, or a piece of masonry. Masonry always implies building; but building does not always imply masonry. *See* MASONRY.

BUILDING ACT, the act passed in the year 1844, known as 7 & 8 Vict. cap. 84, for regulating the construction and the use of buildings in the metropolis and its neighbourhood, within certain limits defined by the act.

As this act is usually appended to Price Books, &c., we have thought it unnecessary to occupy space by giving it here at length.

BUILDING OF BEAMS, the joining of two, or several pieces of timber together in one thickness, and of several pieces in one length, by means of bolts, so as to form a beam of given dimensions, which it would be impossible to obtain from a single piece of timber. Beams thus built, are stronger than such as are scarfed, provided their joints be judiciously strapped across on the exterior sides; and their construction does not require so much waste of timber. Not only beams, but ribs for vaulted roofs, may be built so as to be stronger, and require less timber in their fabrication, than those which are scarfed; and if due attention be paid to their curves, no trussing will be necessary. The practice of building a compound timber, so as to form one mass, or piece, which would perform the function of a single piece, will be found under the article RIB. Other particulars, with regard to the lengthening of beams, will be found under SCARFING.

BULKER, a term used in Lincolnshire for a beam or rafter.

BULLEN-NAILS, those with round heads and short shanks, tinned and lacquered: there are about three sizes of them, which are used in the hangings of rooms.

BULWARK, in ancient fortification, is nearly the same with bastion in the modern. *See* RAMPART and TORUS.

BUNDLE PILLAR, in Gothic architecture, a column consisting of a number of small pillars around its circumference.

BUSCHETTO, a distinguished Grecian architect, born in the isle of Dulichio, and employed, in 1016, by the republic of Pisa, in erecting their cathedral church. This has been reckoned one of the most sumptuous edifices in Italy. He died at Pisa, where he had a monument erected to his memory, with an inscription, intimating his superior knowledge of the mechanical powers. He had many disciples, and is regarded as the founder of modern architectural science in Italy.

BUST, or BUSTO, in sculpture, that portion of the human figure, which comprehends the head, neck, breast, and shoulders. The Italians also apply this term to a greater portion of the human figure, as low as the hips, with or without the head and arms, as in the busts of many illustrious ancient Romans. The word is probably derived from the Latin *bustum.* These pieces of sculpture are generally placed upon a pedestal or console.

BUT-HINGES, those employed in hanging closures, as doors, shutters, casements, &c., placed on the edges with the knuckle projecting on the side on which the closure is to open, and the other edges stopping against a small piece of wood left on the thickness of the closure, so as to keep the arris entire. It is customary to sink the thickness of the hinges flush with the surface of the edge of the closure, and the tail part one-half into the jamb. There are several kinds of but-hinges, such as, *stop but-hinges*, which only permit the closure to open to a right angle, or perhaps little more, without breaking the hinge; *rising but-hinges*, which turn upon a screw, employed in doors, and cause the door to rise in the act of opening, so as to clear a carpet in the apartment. *Slip-off but-hinges*, are those employed where a door or window-blind requires to be taken off occasionally.

BUTMENT. *See* ABUTMENT and STONE BRIDGE.

BUTMENT CHEEKS, the two solid parts on each side of a mortise: the thickness of each of the cheeks should be equal to that of the mortise, when there is no circumstance which may require them to be of a different thickness.

BUTT-END of a piece of timber, the largest end next to the root.

BUTT-JOINT, in hand-railing, a joint at right angles to the curve of the rail. *See* HAND-RAILING.

BUTTERY, the store-room for provisions. Its situation is generally north.

BUTTING-JOINT, that which is formed by the surfaces of two pieces of wood, of which the one surface is perpendicular to the fibres, and the other in their direction, or making an oblique angle with them;—as the joint which the struts and braces in carpentry make with the truss-posts.

BUTTON, a small piece or wood or metal, made to turn round a centre, for fastening a door, or any other kind of closure. The centre in commonly a nail, which should be made round where it is to turn, and the head made smooth.

BUTTON OF A LOCK, a round head for moving the bolt.

BUTTRESS, an erection serving to support a wall or other building, which is either too high otherwise to maintain its position, or is pressed against from the other side by an adventitious force.

Buttresses are so frequent in Gothic architecture as to become a marked and principal feature in buildings of that style; they are placed around the exterior sides of the edifice, usually one between every two windows, and one or two at each of the angles of the building. In the earlier erections, each angle was supported by two buttresses, disposed so as to leave their sides parallel to the planes of the walls; but in later examples, for the sake of giving a lighter appearance to the building, as well as for economizing materials, only one buttress was used, situate in such a manner as to receive the direct drift of the vaulting, having its sides parallel to the vertical diagonal plane which bisects the angle formed by the two planes of the adjoining faces of the building. The use of these projections is not so much to support the weight of the walls, as to resist the outward thrust of the roof, more especially when vaulted.

There are two kinds of buttresses used in Gothic buildings; those that are formed of vertical planes, and attached to the walls, are called *pillared buttresses;* those which rise from the pillared buttresses upon the sides of the aisles, with an arch-formed intrados, and sloping extrados or top, are called *flying buttresses, arc boutants*, or *arch buttresses.*

In few instances perhaps have the mediæval architects shown greater constructive skill than in the erection of buttresses, as is more especially evidenced in their larger structures, such as cathedrals, where by means of them the active force of the vaulting, which would otherwise overthrow

the walls, is borne down harmless outside the building into the earth. By the arc-boutants the drift is carried over the aisles to the upper part of the main buttresses, where, by the gravity of the super-imposed pinnacles, the direction of the force is changed, so that from an horizontal thrust, it becomes or at least approaches to a vertical pressure, which again is carried through the mass of the buttress to the ground at its base. No material is thrown away, all is pressed into active service, what does not answer a useful end is removed, and nothing added merely for ornament; an instance of the latter has been shown in the case of the surmounting pinnacle; which, although by a superficial observer it might be considered as mere ornament, is in reality of the utmost importance in the construction; as an example of the previous statement, may be produced the buttresses at Westminster Hall, from which a considerable portion near the ground and adjoining the walls, being of no service, has been entirely cut away.

Pillared buttresses are enriched with pinnacles, niches, statues, and other ornaments. Flying buttresses are often perforated, particularly in the later examples, in which the perforations assume the form of polyfoils, flambeaux, and other beautiful devices. A rich specimen is to be found in Henry the Seventh's chapel at Westminster, where the buttresses are of a wonderfully light and gorgeous appearance; the main buttresses also in this instance are of a very elaborate description.

BYZANTINE ARCHITECTURE, a style of architecture bordering on the Romanesque, which prevailed in Greece and its dependencies during the early ages of Christianity.

This style may be said to have commenced with the establishment of the Eastern empire, when Constantine transferred the seat of government from Rome to Byzantium, from the name of which city it also derives its distinguishing appellation. Some writers indeed have gone so far as to state that the first Christian emperor removed from the ancient city for the sole purpose of obtaining greater freedom in the establishment of his new religion; solicitous for its purity, that it might remain unpolluted by any mixture with the ancient rites, distinct from paganism even in its architecture. Hope, to whom we are indebted for much information on the subject, states this as his opinion, and says that Constantine, having evaded the restraints which his new creed was subject to at Rome by his removal to Byzantium, set himself diligently to work to establish it on a firm basis: one great object which presented itself to his notice, was the erection of appropriate places of worship, which were much needed, the number of Christians exceeding that of pagans, and there being no previous edifices either of a civil or religious character, which could be conveniently adapted to the purpose. Architects, therefore, were left entirely to their own resources, unless indeed they were willing to copy that class of edifices adopted in the old metropolis; but this does not seem to have been their object, they desired rather to form an entirely new style of building; there were besides no existing edifices of any note, whose materials might tempt their removal to the new structures, and so, to a certain extent, determine their construction, as had been the case at Rome. Under such circumstances originated the peculiar style of architecture which has been since denominated Byzantine.

We have before noticed that the Christians had already outnumbered their heathen adversaries in this city, and as their religion was daily acquiring more and more proselytes, the want of churches must have been daily more apparent; it would be reasonable to suppose, therefore, that a vast number must have been at once erected, and such indeed seems to have been the case, for we are told that no less than eighteen hundred were endowed between the reigns of Constantine and Justinian, a period of little more than two hundred years. Few of these, however, remain: many of the oldest of them were destroyed by earthquakes and fires, principally in the reign of Zeno; and all that survived that period, in the sedition of A. D. 532. This outbreak happened in the time of Justinian, who set zealously to work to repair the losses which had been sustained, and vied with his illustrious predecessor in the erection and restoration of Christian churches.

It must not be supposed that this style of building was all this time confined to its original locality; it had spread rapidly throughout the Eastern empire; where the Eastern churches extended, there also did its architecture extend, from the city of the chief bishop through the whole patriarchate under his jurisdiction. It is remarkable, however, how rarely it found its way into Western Christendom; the first instance of its appearance in that quarter, was the church of S. Nazareo e Celso, at Ravenna, in the year A. D. 440. This church was erected by Galla Placidia, daughter of Theodosius, afterwards married to Constantius Cæsar, and mother of Valentinian; she was regent of the Western empire for some time during the minority of her son, and seems to have been a zealous promoter of the Christian religion; the erection of many churches is attributed to her, amongst which are three or four in this same city of Ravenna. The next we hear of Byzantine architecture in Italy is A. D. 547, at Ravenna again, in the church of S. Vitale, which was erected by Julianus, the treasurer, under the direction of Justinian. The reign of this prince is remarkable for the number of buildings of all kinds erected; bridges, aqueducts, roads, fortresses, and a variety of works of public utility were undertaken throughout the provinces, but the number of churches erected surpassed that of all other structures; new ones were constructed, and old ones re-edified, of which last a great number, as already stated, had been destroyed in the insurrection which occurred in this reign. Of all the restorations which this emperor effected, the most remarkable is that of S. Sophia, at Constantinople; this church he entirely rebuilt, preserving, however, as it would appear, the original plan.

In this same reign the Ostrogoths were driven out of Italy by Narses, one of Justinian's generals, and the Western empire again brought under the rule of one sovereign, which circumstance led to a further introduction westward of Byzantine architecture. Its progress, however, seems to have been more limited than might have been expected, for, with the exception of some of the principal cities where the viceroys held their court, we see but few instances of its adoption. We have already alluded to Ravenna, which was the seat of the principal exarchate, and have now only to refer to the cases of Ancona and Venice, in the former of which is found the church of S. Ciriaco, and in the latter that of S. Mark, though the existence of this style in the latter city is perhaps attributable rather to the mercantile intercourse of the Venetians with the East, than to the authority of the emperor over the western shores of the Adriatic. We have now quoted all the principal examples of this style that have been discovered in the West, at least on the one side the Alps; we make this reservation, for Hope, quoting Fleury, says that the style crossed the Alps, and is to be seen in the old city of Atlas, on the Mediterranean, in the church of S. Cesarius, an erection of the sixth century; he further states that it eventually reached as far north as Paris. Be this as it may, however, putting all the

examples together, it is certain that they number much lower than would naturally be expected; a fact not easily to be accounted for, were it not for one circumstance, the rivalry that existed between the eastern and western churches. As early as the second century, a serious division arose between them respecting the time of celebrating Easter, which proceeded to such an extent, that Victor, bishop of Rome, separated his opponents from his communion. The Roman church, owing to its connection with the metropolis of the empire, as well as from other causes, had obtained an early distinction, which, in process of time, became invidious from the pertinacity with which it was claimed, and the encroachments which it gave rise to under individual bishops. When, however, Constantine removed his court to Byzantium, the see of Constantinople rose suddenly to dignity and power, and showed itself a formidable rival to that of Rome, and a serious hindrance to its usurpations; thus originated a determined jealousy between the two churches, which was manifested by the constant differences which occurred between them, of which there were no less than four in little more than a century and a half, one of twenty-five years' duration, and which led eventually to the final separation in the eleventh century. It is to this rivalry we attribute the paucity of examples in this style of architecture to be met with in the Western empire; an opinion confirmed by Mr. Gally Knight, who, alluding to the subject of our article, says, "This plan became a favourite in the East, and was adhered to in those parts with the greater tenacity, in consequence of the schism which subsequently took place between the pope of Rome and the patriarch of Constantinople. There was to be a difference in every thing. The Greeks insisted upon the square form of their own inventions; whilst all the nations which continued to acknowledge the supremacy of the pope, continued to employ the long form, which was persevered in at Rome." A reviewer of the work from which this extract is made, remarks, "Mr. Knight's observations with regard to the antagonism of the eastern and the western churches, are entirely correct. Except when favoured by peculiar political relations, it is remarkable how little influence was exerted in Italy by Byzantine art. Ravenna and Venice are almost the only localities where we may trace any decided imitation of the type of Constantinople."

There is one passage in this extract which we would desire to qualify, for although Byzantine architecture, as a style, does not seem to have been employed to any extent in the West, still it cannot be said that it possessed no influence in that quarter. That many of its features were imitated in succeeding styles cannot be doubted; its principal characteristics are evident in most of the Lombardic churches, and in the other styles which prevailed in Western Christendom. The Greek church was seldom copied entire; but its different parts were adopted in buildings otherwise of a different character; for instance, in some cases the Greek dome appears in conjunction with the Latin cross; in others, the Greek plan alone is imitated; in others again, both appear together; so that were it not for some peculiarity of arrangement or detail, it would be difficult to decide to which style the building might belong. This kind of influence was exerted not only in Italy, but throughout the whole of Western Europe.

In A. D. 586, the Lombards made their appearance in Italy, and from that time dates the downfall of the previous styles of art, and the introduction of that mode which is entitled, after their designation, Lombardic; not that this may be strictly said to be a new style, but rather a modification of those already existing; still its characteristics are so marked as readily to distinguish it from its predecessors. After this period we see little more of Byzantine architecture beyond the locality where it first originated; in the East it seems to have held out until the invasion of the Ottomans.

The distinguishing characteristic of Byzantine architecture is the dome, a feature which distinguishes it at once from all preceding styles, and no less surely, though perhaps less readily, from its successors; in the one case by its mere presence, in the other by its peculiar form. The adaptation of the sphere throughout the building, may be said to be the mark of the style, for it is used not only in the case of the principal dome, but in a modified form as the covering of the building in every part where it can possibly be applied, as instanced in the conchs over the apsides or extremities of the aisles. We might perhaps speak more generally, and lay down the circle as the standard figure of construction, for it appears every where, in plan, in section, and in elevation, or, as Hope says, "Arches rising over arches, and cupolas over cupolas, we may say, that all which in the temples of Athens had been straight, and angular, and square, in the churches of Constantinople became curved and rounded, concave within and convex without." The plan of the buildings was generally that of a cross inscribed in a square, having each of the arms of an equal length, and not greatly prolonged. At the angles of the square formed at the intersection of the cross were situate four piers, supporting as many arches, whose spandrils converged so as to unite in the form of a circle towards their summit, which again supported the crowning dome. The four arms of the cross terminated in apsides of semicircular plan, and were likewise covered with semi-cupolas, closing over the arches which supported the central dome. The principal entrance was preceded by a porch, and this again by an atrium or open quadrangle, which is seldom omitted in the Eastern churches. The church of S. Sophia is said to have had four distinct nartheces besides the atrium. The domes in this style are generally flat or depressed, of a vertical section less than a semicircle, that of S. Sophia is noted as having been remarkably low; the materials of their construction were always of a light description, frequently hollow jars of a somewhat cylindrical form, fitting one in the other, and made of earthenware or some light substance. The thrust of the dome was most usually resisted by pendentives or brackets springing from the angles of walls, which were square, and carried up to support the base of the dome; but this method was not universally adopted, for in the Church of S. Vitale at Ravenna, the dome is supported by a series of small arches; in this case, however, the plan of the walls is not square, but octagon.

The minor points of distinction are to be found in the details, of which the following are the most remarkable. The heads of apertures are for the most part of a semicircular form, sometimes however of a larger, sometimes of a lesser segment; not unfrequently at a late period, stilted arches are used, that is, semicircular arches having the lower extremities continued downwards perpendicularly;—this method seems to have been adopted for the sake of preserving the same level when arches of different spans were employed. Besides these forms, pointed arches are occasionally met with, also apertures having triangular or pedimental heads. Another peculiarity is the frequent employment of a series of successive arches. The only remaining distinction which we shall notice has reference to the capitals of the columns, which are square, tapering blocks of the form of truncated pyramids having the apex downwards; they are little better than plain blocks, their only ornamentation consisting of foliation in low relief, or a sort of basket-work which is

peculiar to this style of architecture. Nothing further need be said respecting its characteristics, the dome of itself is almost a sufficient feature to stamp the character of the type.

The origin of this mode of building is variously attributed by various writers; some will have it that it is but a modification of the Basilican style, with the addition of the dome, which necessitated the shortening of the oblong of the Basilica; but this, which is considered as merely an addition, is the principal feature both in construction and design. It is true, the plan of the Basilica was an oblong, and that of the Byzantine buildings a square, but surely it does not follow that the latter should have been borrowed from the former; as a matter of fact it may be so, but there is no prima facie evidence in favour of such an opinion, from the mere similarity of plan. Others attribute its origin to the baptisteries, or to the sepulchral chapels built by Constantine, such as that of S. Costanza, the burial-place of Constantia, his daughter, or the Holy Sepulchre at Jerusalem, and it must be confessed that these offer a greater resemblance to the Greek churches than do the Basilicas: others again are of opinion that this was entirely a new style without any previous model, owing its origin to the skill and conception of the Byzantine architects. The question remains, how are these differences to be settled? Not, we presume, by following any one opinion to the exclusion of the others, but by granting a moderate credit to all. We believe that they all speak truly, but that no one of them speaks the whole truth; it is probable that Byzantine architecture owes its origin to each and all of the above sources,—to one perhaps more than another, but not to one to the exclusion of another. We would say that it owed its existence not a little to the two first causes, but more especially to the last, for as Mr. Knight, in describing the church of S. Vitale, says, "The chief architectural novelty in this building, is the dome. No vaulting of any kind had ever been hitherto employed in the roofs of churches, much less that most skilful and admired of all vaulting, the cupola, or dome; a mode of covering buildings perfectly well understood by the Romans, but discontinued as art declined, and, for the first time, reproduced by the Greek architects of Constantinople, in the instance of S. Sophia."

With the insufficient materials we have to work upon, it would be futile to attempt a detailed classification of the examples belonging to this style. It is to be regretted that our knowledge on the subject is so scanty, but we trust that some of our travellers will take an interest in those hitherto neglected remains of Christian art. That there is a scarcity of examples, we can hardly suppose; we believe that Asia Minor would afford ample materials for a proper investigation. The only writer we know of who has essayed an arrangement of known examples, and their division into classes, is M. Couchaud in his book on the Eglises Byzantines en Grèce. It is true he seems to include some examples under this style which other authors do not suppose to belong to it, but he has given considerable attention to the subject, and his opinions cannot but be worth consideration. He commences by dividing the buildings into three classes, to each of which he assigns a particular period. The first period is comprised between the fourth and sixth centuries, the second between the sixth and eleventh, and the third between the eleventh and the invasion by the Ottomans. We cannot do better than follow his own description as closely as possible.

Few of the churches of the first period, says he, are now extant; but we learn from the historian Eusebius that they were in plan either round or octagon, and were surmounted by a dome. Of this description was the church erected by Constantine at Antioch, which was of the latter class, and that erected by his mother Helena, in Syria, of the circular form. The churches of S. Marcellin and S. Constance at Rome, as well as that of S. Vitale at Ravenna, afford further examples of the historian's description. The plans in both cases, whether circular or octagonal, terminated of a square form, and upon the plans thus produced were erected the façades; the most ancient of which are simple parallelopipeds, terminated at their summit by a cornice of stone or marble, and sometimes of bricks, so placed as to form salient and re-entering angles. Pediments showing the slope of the roof do not appear in the façades, for the use of timber had already been discarded by the Greeks in the formation of their roofs, which were now either flat or spherical. One or more gates gave admittance into the church, and these were generally adorned with deep mouldings; the lintels were relieved by an arch of discharge. We have said that all the churches of this period were surmounted by domes; these were pierced at their lower extremity by a multitude of apertures which lighted the interior of the cupola. According to Eusebius and S. Paul of Seleucia, the domes were covered with lead and occasionally gilded, but all those which are still to be found in Greece are covered with tiles of terra cotta. The lateral façades differ little from the principal one; they are each of them provided with an entrance. The apsides, generally three in number, symbolizing the three Persons of the Holy Trinity, were of a simple plan, which was more frequently circular than polygonal: their sides were pierced with one or more apertures or windows. In the interior of the church the nave was always preceded by a porch or vestibule. A gallery for the female portion of the congregation was carried along the nave as far as the sanctuary, and was lighted by windows situated over the principal façade, and sometimes by others in the side façades. The principal difference between the styles of the two empires, is shown in the length of the nave, which in the Greek churches is much shorter than in the basilicas of the west. In the centre of the church were four piers supporting the dome, which was erected on a square plan, the angles being filled up by very ingenious contrivances technically termed pendentives. The extremities of the nave were covered by two hemispherical cupolas.

Such are the principal features of the edifices which were erected from the time of Constantine to the middle of the sixth century.

An enumeration of the peculiarities of the second period will help to give us an idea of the progress made by Justinian in the Christian architecture of this era.

The first edifice which presents itself to our notice is the smaller church of S. Sophia at Constantinople, converted into a mosque after the invasion of the Ottomans. The plan of the exterior is that of a square surrounding an octagon, the form of that of S. Vitale at Ravenna. In the interior the galleries for females were carried round the first story, and the nave covered, as in the preceding period, with a dome. From this let us pass on to the larger church of the same name, a building erected by Justinian to replace one which had not long previously been destroyed by fire. In plan this is similar to the smaller church, with the exception that the octagon is slightly prolonged. The interior galleries are similar to those already described, but the dome is more rich and beautiful than in all previous examples, and pierced with a larger number of apertures. The effect produced by this building was great, as is evidenced by the influence which it obtained throughout the Eastern empire. At a later time, the form of the interior was repeated in the exterior; this combination, which was first applied to the nave

and transepts, at last became so general, that externally you could scarcely discover a straight line towards the summit of the building. The churches of "the Almighty," and of the monastery at Constantinople, which still preserve the roof of this period, offer remarkable examples of this combination of vaulting; and the method, which was employed in a great number of instances, is still to be seen in most of the isles of the Archipelago. In this period the domes were increased in number, and at last were carried even over the porch; the side façades follow the same form as the principal one, and the rear end of the edifice terminates in a polygonal apsis, pierced with windows of two or three compartments. In the interior decoration mosaics took the place of the marble slabs previously employed, which were retained only in the surbasements. The nave was simplified; square piers were substituted for columns, which gradually disappeared, and the pendentives were modified and somewhat varied. The vaults were divided by horizontal rings, and decorated with paintings; the centre of the cupola being occupied by a colossal head of Christ, surrounded by angels. The domes belonging to the latter portion of this period differed from the preceding, inasmuch as the windows encroached upon the spherical part, whereas before they had been confined to the base. This second period, as may readily be seen, added greatly to the embellishment of Byzantine architecture, and eventually considerably modified its character.

In the third period, the systems of Italy and Greece were united; the division indeed owes its origin, in a great measure, to the Roman basilica, as is manifested by the gable ends of the wall showing the inclination of the roof. Athens furnishes a number of examples, in which the influence of Western type is particularly noticeable. The galleries for females were now dispensed with, and a portion of the area of the church set apart for their service in the transepts. The influence of this new mode, however, was more especially shown in the profusion and richness of the ornaments employed in the details of the buildings.

Paintings in fresco took the place of mosaics, and were multiplied to such an extent, that at last the very marble which previously adorned the surbasement, was imitated by this means.

Semicircular vaults covered the whole length of the church; the windows were closed up with slabs of stone or marble, pierced with small circular apertures to admit light; and the doors began to be of more elaborate workmanship; the interior arrangement remained the same as before. This last period, which has been said to end with the invasion of the Turks, may be considered as continuing for some time longer, during which the arts remained stationary in Greece, up to the period of the last war of independence.

It now only remains to give some description of a few of the churches which have been alluded to in a previous part of this article: we cannot do better than commence with that of S. Sophia, which forms a fair type of the whole style. The following extract is taken from the *Encyclopedia Metropolitana*:—

"The cathedral of S. Sophia, at Constantinople, which had been built by Constantine, having been twice destroyed by fire, was rebuilt finally by Justinian, about A. D. 532. His architect, Anthemius, gave the design, and the emperor every day superintended the wotk, which was completed in about six years from the time of laying the foundation; the magnificence of the edifice so well satisfied the emperor, that he is said to have glorified himself with the reflection that in it he had exceeded Solomon himself.

"The plan of the interior is that of a Greek cross, the four arms of which are of equal length; the central part is a square, the sides of which are each about 115 feet long. At each angle of the square a massive pier of travertine stone has been carried to the height of 86 feet from the pavement, and four semicircular arches stretch across the intervals over the sides of the square, and rest upon the piers. The interior angles between the four piers in the central square are filled up, from the springing points of the four arches, in a concave form, to a horizontal plane passing through their vertices, which are at 143 feet above the pavement; so that, at the level of the vertices, the interior edge of the part filled up becomes a circle, the diameter of which is equal to the side of the central square. Upon this circle, as a base, is raised the principal dome, the form of which is that of a segment of a sphere, which is said to be equal in height to one-sixth of the diameter of the base. On both the eastern and western sides of the square, in the centre of the church, is a semicircular recess, the diameter of which is nearly equal to the side of the square; it is carried up to the same height as the piers, and terminates in a half-dome, or quadrant of a sphere, its base resting upon the hemicylindrical wall of the recess, and its vertical side coinciding with the arch raised between the piers on the face of the building; the flat side of each recess and dome being open towards the interior of the church. These quadrantal domes were intended to resist the lateral thrust of the arches raised on the northern and southern sides of the church, but they were found insufficient, for the arches pushed away the half-dome on the eastern side twice, and it could only be made to stand by constructing the great dome of pumice stone and very light bricks obtained from Rhodes, by filling up the arches with others of smaller dimensions, and by carrying an enormous arch-buttress from a massive wall beyond the building to the foot of the dome.

"At the extremities of the semicircular recesses, in a line running east and west through the centre of the church, are smaller recesses, the plan of one of which terminates in a semicircle, and of the other in a right line; these recesses are built to the height of the springing of the four principal arches, and are crowned by quadrantal domes, which, as well as the recesses, are open towards the interior. In each of the two principal hemicylindrical recesses between the great piers, and the other recesses just mentioned, are formed two other cylindrical recesses, open towards the interior, and covered by quadrantal domes. All the recesses and domes are perforated by rows of small windows to obtain light.

"On both the northern and southern sides of the square, in the interior of the church, is a grand vestibule forming a square on the plan; the roof of each consists of three hemicylindrical vaults extending from north to south, and of another vault of the same kind crossing the former at right angles through the middle, and forming, by their intersections, three groined arches; these vaults are supported by massive pillars, which have bases, but no plinths; the upper part of their capitals resemble the volutes of the Ionic order, but the lower part seems to be a barbarous imitation of the Corinthian base. Above these vestibules are galleries exactly similar to them, and, probably, appropriated to women during the performance of divine service. The whole church is surrounded by cloisters, and enclosed by four walls, forming one great rectangle on the plan. The exterior does not correspond with the internal grandeur of the edifice, being surrounded by clumsy buttresses. The entrance is by a portico as long as the church, and about 36 feet wide; this is ornamented with pilasters, and communicates with the interior by five doorways of marble, sculptured with figures in bas-relief. Contiguous to this

vestibule, and parallel to it, is another, which has nine doorways of bronze.

"After twenty years, the Eastern dome was thrown down by an earthquake, but it was immediately restored by the persevering industry of Justinian; and it now remains, after a lapse of thirteen centuries, a stately monument to his fame."

The next description, that of S. Vitale, Ravenna, is given by Mr. Gwilt, in his Encyclopædia of Architecture.

"The exterior walls are formed in a regular octagon, whose diameter is 128 feet. Within this octagon is another concentric one, 54 feet in diameter, from the eight piers whereof—55 feet in height—a hemispherical vault is gathered over, and over this is a timber conical roof. The peculiarity exhibited in the construction of the cupola is, that the spandrils are filled in with earthen vases, and that round the exterior of its base, semicircular-headed windows are introduced, each of which is subdivided into two apertures of similar forms. Between every two piers hemicylindrical recesses are formed, each covered by a semidome, whose vertex is 48 feet from the pavement, and each of them contains two windows, subdivided into three spaces by two columns of the Corinthian order, supporting semicircular-headed arches. Between the piers and the external walls are two corridors, which surround the whole building, in two stories, one above the other, each covered by hemicylindrical vaulting. The upper corridor, above the vault, is covered with a sloping or lean-to roof."

Mr. Hope adds the following particulars:—"S. Vitale," says he, "built under Justinian in 534, announces itself at first sight as a work of Greek architects, and a kindred production with S. Sophia, and the others of Constantinople. Its form, round without, though octagonal within; its two tiers of arcades supported on pillars; its larger arcades or apsides, containing lesser arches or pillars; its square capitals, partly of basket-work, and its coating of Mosaic, at once complete the resemblance and establish the relationship."

The next descriptions, of S. Ciriaco, at Ancona, and S. Mark's, Venice, are taken from Mr. Gally Knight's beautiful work on the Ecclesiastical Architecture of Italy.

"Ancona was one of the towns of Italy which remained longest in the hands of the emperors of the East. Muratori informs us, that in the year 1174 Ancona was governed by an officer appointed by the Emperor Comnenus, and he adds, that the Emperor Frederick saw with impatience that remnant of Oriental power in the heart of the Western Empire. These circumstances will sufficiently account for the plan and style of S. Ciriaco, which, constructed under the domination of the Greeks, is Greek in all its parts.

"No certain record of the date of this building has been preserved, but from an inscription still extant, it appears that the bodies of SS. Ciriaco, Marcellino, and Liberio, were deposited in the crypt of this church in the year 1097. Almost invariably, when the bodies of saints were translated, a new church was prepared for their reception, and the translation usually took place when the building was sufficiently advanced for the performance of divine service, but before the work was entirely completed. We further find, that Bernard, Bishop of Ancona, consecrated a high-altar in 1128, and that in 1189, Bishop Beraldus added a chapel, and encrusted the walls of the interior of the church with marble. From all these circumstances, it may be inferred, that this cathedral was begun about the middle of the eleventh century, and completed in the course of the twelfth. It is highly probable that the Saracens, who landed at Ancona in 983, and committed extensive devastations, maltreated the cathedral, which was then in existence, and made it necessary to provide another in peaceable times.

"The cathedral was originally dedicated to S. Lawrence, and retained that name till so late as the fourteenth century, but finally the local favourite obtained the ascendant. The body of S. Ciriaco was originally imported from the East by the empress Galla Placidia in the fifth century, and by her deposited in the cathedral which then existed at Ancona.

"S. Ciriaco is on a large scale. The plan exactly represents the Greek cross, and was probably supplied by a Greek architect. The centre of the building is surmounted by the Eastern cupola. The building appears to have been erected without any deviation from the original design, and for the most part remains as it was at first constructed. The principal porch, which projects boldly, and is enriched with numerous mouldings, must have been a subsequent addition, as the courses of the stones of which it is composed, do not correspond with those of the church. In the interior, pillars supporting round arches, divide the nave from the aisles. The capitals of these pillars imitate the Corinthian, and exhibit no admixture of the Lombard imagery, which, at the time when the cathedral was built, prevailed in the north of Italy. The cupola is supported by piers and arches. The arches under the dome are pointed, but are evidently alterations. These pointed arches may have been introduced by the celebrated architect, Margaritone, who flourished in the second half of the thirteenth century. Margaritone was very much employed at Ancona, and to him the entire construction of S. Ciriaco is attributed erroneously by Vasari. Margaritone may have added the porch."

"The plan of S. Mark's, like that of S. Sophia, is a Greek cross, with the addition of spacious porticos. The centre of the building is covered with a dome, and over the centre of each of the arms of the cross, rises a smaller cupola. All the remaining parts of the building are covered with vaults, in constructing which, the Greeks had become expert, and which are much to be preferred to the wooden roofs of the old basilicas. Colonnades and round arches separate the nave from the aisles in each of the four compartments, and support galleries above. The capitals of the pillars imitate the Corinthian, and are free from the imagery which at that time abounded in the other churches of Italy. It is computed, that in the decoration of the building, without and within, above five hundred pillars are employed.

"The pillars are all of marble, and were chiefly brought from Greece and other parts of the Levant. Whilst S. Mark's was building, every vessel that cleared out of Venice for the East, was obliged to bring back pillars and marbles for the work in which the republic took so general an interest."

"The external appearance of S. Mark's is no less Byzantine than its interior, but less resembles S. Sophia from the increased numbers and elevation of its cupolas. Succeeding generations endeavour to outstrip their predecessors, and in the interval which had elapsed between the construction of S. Sophia and that of S. Mark's, the Greek architects had multiplied the feature which had obtained so much admiration, and had sought to give it additional importance, and surmounted the hemisphere of the dome with a second cupola of wood covered with lead. This change was imparted to the Venetian copy.

"Another Byzantine feature is conspicuous in the exterior of the building in the tiers of round arches by which the flank walls are relieved. With a singular contrast to the habits of their forefathers, who inflexibly adhered to the horizontal, the Greeks of the lower Empire turned

every line into a curve, and introduced a semi-arch wherever they could, even in the shape of windows, which were often what in modern phraseology would be termed fan-lights. The front is on the same principle: a second tier of semicircular arches rises over the portico, which consists of no less than five semicircular entrances decorated with numerous pillars; the summit is crowned with spiral and pyramidal forms, partaking more of the character of the pointed style than of the round. Altogether, the exterior of S. Mark's is a strange mixture, but it is venerable and picturesque."

The last description which we shall give is that of S. Theodore, at Athens; it is extracted from M. Couchaud.

"Of all the churches which Athens possesses, S. Theodore is certainly the most complete, since it has three apsides, a dome and belfry; but the fresco painting in the interior has decayed. The altar-screen, the furniture, and the pulpit, have been replaced. It is constructed of a porous stone, separated by courses of brick; the only peculiarity which it offers is a frieze in terra cotta, running along the front façade, and the two side façades, which are pierced with doors of singular proportion, and having a horse-shoe-headed arch."

C.

CAABA, a part of the temple of Mecca, to which the Mahometans principally address themselves in prayer. It consists of a stone edifice, nearly square, and is said, by the followers of Mahomet, to have been first built by Abraham and his son Ishmael.

The word is Arabic, *caaba*, and *caabah;* a name which some have given to this building, on account of its height, which exceeded that of the other buildings in Mecca; but others, with more appearance of propriety, derive the name from its quadrangular form.

This edifice is so ancient, that its original use, and the name of its builder, are lost in a cloud of idle traditions; it is not improbable, however, that it was built by some of the immediate descendants of Ishmael. But, whatever was the original destination of the building, it does not seem to have been a temple, as the door was not placed in the middle of the structure; and for many ages there was no worship performed in it, though the pagan Arabs went in procession round it. It is most probable, however, that the Caaba was primarily designed for religious purposes; and it is certain, that it was held in the highest veneration long before the birth of Mahomet. Having undergone several reparations, it was, a few years after his birth, rebuilt, on the old foundation, by the tribe of Koreish, who had acquired possession of it, either by fraud or force. It was afterwards repaired by Abdallah Eben Zobeir, the calif of Mecca; and again rebuilt by Yussof, surnamed Al Hejâj, in the seventy-fourth year of the Hegira, with some alterations, in the form in which it now remains.

The length of the Caaba is twenty-four cubits, from north to south; its breadth, from east to west, twenty-three cubits; the door, which is on the east side, is raised four cubits from the ground, and the floor is on a level with the threshold of the door. The Caaba has a double roof, supported by three octangular pillars of aloes-wood. The outside of the building is covered with rich black damask, adorned with an embroidered band of gold, which is changed every year, and which is provided by the Turkish emperors. At some distance, the Caaba is surrounded, but not entirely, with a circular enclosure of pillars, joined at the bottom by a low balustrade, and towards the top by bars of silver. Without this enclosure, on the south, north, and west sides of the Caaba, are three buildings, which are the oratories, or places where three of the orthodox sects assemble to perform their devotions; and towards the south-east stands the edifice which covers the well Zemzem, the treasury, and the cupola of Al Abbas. All these buildings are enclosed, at a considerable distance, by a magnificent piazza, or square colonnade, covered with cupolas. From each angle of this piazza rises a minaret, with a double gallery, adorned with a gilded spire and crescent, as are the cupolas which cover the piazza. Between the pillars of both enclosures, hang a great number of lamps, which are constantly kept lighted by night.

CABLE, a moulding of a convex circular section, rising from the back or concave surface of a flute, so that its most prominent part may be in the same surface as the fillet, on each side of the flute; the surface of the flute being that of a concave cylinder, while that of the cable is the surface of a convex cylinder, with the axes of the cylinders parallel to each other. A cable represents a rope or staff laid in the flute; it is always shorter than the flute, and placed at the lower end of it.

Cable mouldings of a somewhat different character are made use of in Norman architecture; they represent cables or twisted ropes, laid in mouldings of a concave circular section, and having one half or greater portion of their bodies exposed, and projecting from their beds.

Cabled Flutes, such flutes as are filled with cables.

CABLING, the filling of flutes with cables, or the cables themselves so disposed. Cabling the flutes of columns was not in very frequent use in the works of antiquity. The flutes of the columns of the arch of Constantine are filled with cables to about one-third of the height of the shafts. Most of the columns in the ruins of Balbec, Palmyra, and Dioclesian's palace at Spalatra, have neither flutes nor cables. Cabling has sometimes been practised in modern times, without fluting, as in the church of Sapienza, at Rome. *See* Flutes.

CAGE, in carpentry, an outer work of timber, enclosing other works within it; as, the cage of a stair, is the wooden wall that encloses it.

CAISSON, in water-building, a large chest of strong timber, made water-tight, and used in large and rapid rivers for building the pier of a bridge. The bottom consists of a grating of timber, so contrived as to be detached from the sides when necessary. The ground under the intended pier is first levelled, and the caisson being launched and floated to a proper position, is sunk, and the pier built as high as the level of the water, or nearly so; then the sides are detached, and the bottom remains as a foundation for the pier.

The most considerable work that has come to our knowledge, where caissons have been used, is Westminster Bridge; of this, therefore, a particular account may be acceptable. Each of the caissons contained 150 loads of fir timber, and more tonnage than a man-of-war of 40 guns; their size was

nearly 80 feet from point to point, and 30 feet in breadth; the sides, 10 feet in height, were formed of timbers, laid horizontally over each other, pinned with oak trunnels, and framed together at all corners, except the salient angles, where they were secured by proper iron work, which being unscrewed, would permit the sides of the caisson, had it been found necessary, to divide into two parts. These sides were planked across the timbers, inside and outside, with 3-inch planks, in a vertical position. The thickness of the sides was 18 inches at the bottom and 15 inches at the top; and in order to strengthen them the more, every angle, except the two points, had three oaken knee-timbers, properly bolted and secured. These sides, when finished, were fastened to the bottom, or grating, by twenty-eight pieces of timber on the outside, and eighteen within, called *straps*, about 8 inches broad and 3 inches thick, reaching and lapping over the tops of the sides; the lower parts of these straps were dovetailed to the outer kirb of the grating, and kept to their places by iron wedges. The purpose of these straps and wedges was, that when the pier was built up sufficiently high above low-water mark, to render the caisson no longer necessary for the masons to work in, the wedges being drawn up, gave liberty to clear the straps from the mortises, in consequence of which the sides rose by their own buoyancy, leaving the grating under the foundation of the pier.

The pressure of the water upon the sides of the caisson was resisted by means of a ground timber, or ribbon, 14 inches wide, and 7 inches thick, pinned upon the upper row of timbers of the grating; and the top of the sides was secured by a sufficient number of beams laid across, which also served to support a floor on which the labourers stood, to hoist the stones out of the lighters, and to lower them into the caisson.

The caisson was also provided with a sluice to admit the water. The method of working was as follows: a pit being dug and levelled in the proper situation for the pier, of the same shape as the caisson, and about 5 feet wider all round; the caisson was brought to its position, a few of the lower courses of the pier built in it, and sunk once or twice, to prove the level of the foundation; then, being finally fixed, the masons worked in the usual method of tide-work. About two hours before low-water, the sluice of the caisson, kept open till then, lest the water, flowing to the height of many more feet on the outside than on the inside, should float the caisson and all the stone-work out of its true place, was shut down, and the water pumped low enough, without waiting for the low ebb of the tide, for the masons to set and cramp the stone-work of the succeeding courses. Then when the tide had risen to a considerable height, the sluice was opened again, and the water admitted; and as the caisson was purposely built but 16 feet high, to save useless expense, the high tides flowed some feet above the sides, but without any damage or inconvenience to the works. In this manner the work proceeded till the pier rose to the surface of the caisson; when the sides were floated away, to serve at another pier. (Labelye's *Description of Westminster Bridge*.)

Caisson, signifies also the sunken panel in a vaulted ceiling, or in the soffit of a cornice.

CALATHUS, the work-basket of Minerva: also a hand-basket, made of light wood or rushes, used by the women for gathering flowers, after the example of Minerva. The figure of the calathus, as represented in ancient monuments, is narrow at the bottom, and widens upwards in its horizontal dimensions. Also a cup used in sacrifices.

CALCAREOUS CEMENTS. *See* Cements.

Calcareous Earth, a sort of earth which becomes friable by burning, and is afterwards reduced to a fine powder by mixing it with water; it also effervesces with acids. It is frequently to be met with in a friable or compact state, in the form of chalk. *See* Limestone and Gypsum.

CALENDARIO, Philip, a celebrated architect and sculptor, who flourished at Venice about the year 1354, and constructed those beautiful porticoes round the Palace of St. Mark, which established his fame.

CALIBRE, or Caliber, the greatest extent or diameter of a round body.

Calibre Compasses, or Callipers, a pair of compasses with bent legs, for taking the thickness of a convex or concave body in various parts.

CALIDUCTS, (from *calor*, heat, and *ducere*, to lead,) pipes or canals disposed along the walls of houses and apartments, used by the ancients for conveying heat to the remote parts of the house, from one common furnace.

CALLIMACHUS, a celebrated architect of antiquity, inventor of the Corinthian order.

CALOTTE, a concavity in form of a cup or niche, lathed and plastered, to diminish the height of a chapel, cabinet, or alcove, which would otherwise be too elevated for the breadth.

CAMAROSIS, (from *καμαροειν*, to *arch over*,) an elevation terminated with an arched or vaulted head.

CAMBER, an arch on the top of an aperture, or on the top of a beam; hence camber windows.

Camber Beams, those which are cut with an obtuse angle on the upper edge, forming a declivity each way from the middle of their length; they are used in truncated roofs, where, after being covered with boards, the boards are again covered with lead, in order to discharge the rain-water towards each edge of the flat, or platform.

Cambered beams are employed in a multitude of situations where great strength is required. All beams which are so situate as to be subject to cross-strain should be cambered. Instances of cross-strain occur in bressummers, which are loaded with a wall, and of course are most affected by the gravity of its materials where the bearing is greatest, which will be in their mid-length. A weight applied in this manner will have the effect of pressing the centre below the level of the ends of the beam, and thus fracturing the superincumbent wall; and besides this, will tend to snap and tear asunder the timber; and although, on account of its great scantling, such an event rarely, if ever, occurs, yet it strains the beam in the direction of its length, a test which timber should not be subjected to. Moreover, in all cases where beams of any great length are employed, the gravity of the timber itself will weigh them down midway, even where they are subjected to no additional weight, as in the case of the tie-beams of a truss. In all these instances the difficulty may be obviated by cambering the timber upwards. This method not only ensures that the beam shall be level after settlement, but entirely alters the nature and operation of the force; for whereas previously the beams were strained or extended, this tension, by the employment of a camber, is changed into a pressure, so that the tendency instead of being to tear the particles asunder, and thus weaken or break the timber, is rather to press them more closely together, and render the beam firmer and more compact.

Further, all timber is liable to shrinkage by the evaporation of the moisture which is always present in a greater or less degree, and thereby becomes of smaller dimensions than when first inserted in a building. This defect may be rectified as far as the length is concerned, by cambering to such a degree, that when the wood is completely dry, it may fall into a horizontal position, or nearly so. The extent to which the beam should be bent is a matter of nice calculation, and

the regulation of it must be left to experience. In trusses the camber of the tie-beam should not be too great, as if so, it will tend to thrust out and derange the principals. When bressummers occur one above another, the higher ones should be cambered to a greater extent than those below, the camber increasing in direct proportion to the number of bressummers beneath it.

CAMERATED, arched.

CAMES, in glazing, small slender rods of cast lead, about 12 or 14 inches long, to be drawn through a vice, in order to make turned lead; each such bar is called a *came*.

CAMP CEILING, a ceiling formed by one or more planes, with inclinations rising at an internal obtuse angle from the sides of the apartment, and most frequently enclosing a level plane in the middle, in the manner of a coved ceiling. This kind of ceiling is chiefly used in garrets, where otherwise there would be a want of head-room.

CAMPANA, the body of the Corinthian capital, otherwise called the *vase* or *bell*, from its figure.

CAMPANILE, (from *campana*, a bell,) a bell-tower, chiefly in use among the Italians. It was sometimes a distinct and separate building of itself; but more commonly adjoining to the church, so as to make a part of the fabric, usually at the west end. Several of these towers are remarkable for being considerably out of the perpendicular, of which those of Pisa and Bologna are the most celebrated.

Campaniles were erected to a great height; that of Cremona, the highest in Italy, is 395 feet high; that of Florence, built by Giotto, 267 feet, of a square plan, the sides of which are 45 feet in length. The leaning tower of Pisa is 150 feet in height, and 13 feet out of the perpendicular.

CANAL OF THE IONIC VOLUTE, the spiral channel or sinking on the face, which begins at the eye, in a point, and expands in width until the whole number of revolutions are completed. In the volutes of the Ionic order of the temples of Minerva Polias and Erectheus, at Athens, are several canals, which begin and end in the manner above described.

CANAL is also used for a FLUTE.

CANAL OF THE LARMIER, the channel recessed upwards on the soffit, for preventing the rain-water from reaching the bed or lower part of the cornice. *See* BEAK.

CANARDIERE, or GUERITE, a small turret, sometimes of wood, and sometimes of stone; used as a sentry-box on the salient angles of works, as places of shelter for sentinels. They were formerly constructed on castles, and used for firing, or discharging anything unseen in unmolested security.

CANCELLI, latticed windows, or those made with crossbars of wood or iron. Also balusters or rails, especially those which separate the chancel from the body of the church.

CANOPY, a magnificent covering suspended over an altar, throne, tribunal, pulpit, chair, or the like. *See* BALDACHIN. It also denotes the projecting head of Gothic niches or tabernacles.

CANT, a term used by carpenters, signifying to turn a piece of timber, which is brought in the wrong way for their work. Also, the external angle made by any two planes of a solid or building.

CANT MOULDING, a bevelled surface, or one that is neither perpendicular to the horizon nor to the vertical surface of the body or building. These mouldings are of very remote antiquity, and have an effect similar to the Grecian echinus. A cant moulding, instead of the echinus, is applied to the capital of the columns of the portico of Philip, king of Macedon, and in many other situations, both of Grecian and Roman edifices, as is exhibited in Stewart's *Ruins of Athens*, in the *Ionian Antiquities*, and in Adams's *Ruins of the Palace of Dioclesian, at Spalatra, in Dalmatia*. The mouldings of our first Saxon buildings were originally very simple, consisting only of surfaces perpendicular and parallel to the naked of the walls; though afterwards they were formed not only of squares, but of cants also. These simple forms continued in use for some time after the Conquest; and even when a great variety of curved forms came to be introduced, they were never entirely laid aside; we find them frequently employed in the windows of castellated buildings, and other parts.

CANTED COLUMN, a column of which the horizontal sections are polygons, consisting of straight sides instead of concave sides or flutes. Canted columns are not frequently to be met with in the works of the ancients, yet examples may be seen in the columns of the portico of Philip, king of Macedon, and of the temple of Cora. The cants of columns are difficult to execute with truth, so as to preserve the arrises in the proper contour of the column, and in a vertical plane passing through its axis; and when done, they want the beautiful contrast of light and shade, which is so conspicuous in the flutings of the Grecian Doric.

CANTING, the cutting away a part of an angular body at one of its angles, so that the section may be a parallelogram, the edges of which are parallel from the intersection of the adjoining planes.

CANTALIVERS, those blocks which are placed at regular distances, projecting at right angles from the surface of the wall, and supporting the upper members of a cornice, the eaves of a house, or balcony: they answer the same purpose as modillions, mutules, blocks, or brackets, although they are applied to more trivial purposes; modillions, mutules, &c., being employed in regular architecture. Cantalivers are frequently made of timber, or cast iron, and project to a great distance. Those used in the cornice of St. Paul's, Covent Garden, are of timber, and project one-fourth of the height of the column.

CANTHARUS, among ecclesiastical writers, a fountain or cistern in the middle of the atrium, before the ancient churches, wherein people washed their hands and faces before they entered.

CANTHARUS OF A FOUNTAIN, with the Romans, the part, or apparatus, out of which the water issued; it was of various fanciful forms, sometimes resembling a shell, at others, an animal vomiting the water from its mouth, and sometimes the stream issued through the eyes.

CANTHERS, or CANTERII, in ancient carpentry, the common rafters of a roof, or those placed in vertical planes at right angles to the ridge or eaves of the building.

CANTING STAIRS. *See* STAIRS.

CANTONED BUILDING, a building whose angles are adorned with columns, pilasters, rustic quoins, or anything that projects beyond the naked of the wall.

CANTONED COLUMNS. *See* COLUMNS.

CAP, the mouldings which form the head of a pier or pilaster.

CAP, in joinery, the uppermost part of an assemblage of principal or subordinate parts. The term is applied to the capital of a column, the cornice of a door, the capping or uppermost member of the surbase of a room, the hand-rail of a stair, when supported by an iron strap, &c.

CAPACITY, in geometry, the solid content of a body.

CAPITAL, (*capitello*, Italian; from the Latin, *caput*, the head) the assemblage of mouldings or ornaments above the shaft of a column, on which the entablature rests; in other words, the head of the column. Capitals are variously composed, some with simple mouldings, others with mouldings, foliage, and volutes.

The capitals used in the architecture of the Greeks, though with numberless minute variations of ornaments and proportions, arrange themselves into three general classes, and offer the most obvious distinctions between the orders.

In all the orders, the capital is divided from the shaft by some small member, as an astragal and fillet, or by one or three channels, which are always accounted a part of the shaft; so much of the column, therefore, as appears above this member, belongs to the capital.

The Doric capital consists of a neck, which is a continuation of the shaft, with its fluting, several fillets, varying from three to five in number, a bold projecting ovolo, and a massy abacus, of a square form, which covers the whole.

The Ionic capital consists of an ovolo above the astragal of the shaft; a band, or festoon, upon the ovolo, on the front and rear of the capital, with volutes on the right and left, suspended from the ends of each band, or festoon; and, lastly, a thin moulded abacus crowns the whole.

The Corinthian capital, which is more richly ornamented, consists of a vase, two rows of leaves attached to the vase, volutes, caulicoli, which spring between each two of the upper row of leaves, and, lastly, an abacus, which is not only moulded on all the four edges, but formed into a concavity from the two extremities of each of the said edges.

From this description of Grecian capitals, it will be seen that though the parts are generally so very unlike as to be incapable of comparison, yet they in variety maintain a general resemblance.

The variations to be found in different ancient examples of the same order, will be described under their respective heads.

With regard to the Tuscan capital, there are no authenticated remains of the order of which it is a part; and the precepts of Vitruvius on this head are so obscure, that modern compilers of systems of architecture have, of course, varied exceedingly in their designs; so that the order which passes under this name, must be regarded rather as a modern than an ancient invention. It is made to differ from the modern Doric by an air of poverty and rudeness, and by the suppression of the triglyphs, mutules, and other members.

The Composite appears never to have been admitted as a separate order by the ancients.

From the remains of Egyptian antiquities, we find that their architects had no certain rules; and it is rather singular, that though the buildings themselves were constructed with the greatest simplicity, their capitals are of infinite variety; many of them possessing richness of decoration, although devoid of the simple elegance which is the characteristic of the Grecian orders. The ornaments are, in general, accurate imitations of the natural productions of the country, such as the lotus, the reed, or the palm.

The temples of the ancient inhabitants of Hindostan, works of dateless antiquity, present many capitals of extraordinary form and composition. In some, we find represented the figures of elephants and horses, apparently crouching under the weight of the ceiling. Capitals, very similar in idea, are also found in the ruins of Persepolis, composed of horses and camels.

As Roman art degenerated with the decline of the empire, the capitals from the ancient edifices were used indiscriminately in the new structures; and this led, in later times, to the employment of a variety of capitals in the same edifice. The first alteration we find in the form of this member of the column, is in the erection of that style of architecture known as Byzantine, in which the capitals are in the shape of a truncated pyramid of four sides, placed in an inverted position, having the apex downwards; the surface is ornamented with foliations in low relief, or with a sort of basket-work, which is a distinguishing feature of the style to which it belongs. A nearer approach to their original is shown at a later period, in the style whose introduction is attributed to the Lombards; in this, which is merely a modification of the debased Roman, some of the capitals bear a great resemblance to the Corinthian, although far inferior to their original in simplicity and elegance; there are, however, other examples of a far different description, both in form and ornamentation; some ornamented with designs in low relief, others again of a grotesque character. If we include the Norman in this style, to which it certainly bears a close affinity, we shall have a great variety of forms, to be noted indeed rather for their variety and massive appearance, than for beauty of outline or decoration.

But of all capitals, those found in buildings in the modes commonly comprised under the term Gothic, hold a lofty pre-eminence, both for variety and tastefulness. What can be more chaste and elegant than the ornamentation of the early English? or what more graceful and natural than the foliage of the decorated capital? As to variety, it was the governing principle of decoration, there seldom being found many repetitions of one form in the same building. Nature was their model, by her alone were their designs limited, so long at least as their skill was sufficient to imitate her productions.

Capital, *Angular*. *See* Angular Capital.

Capital of a Baluster, one similar to those of the Tuscan or Doric orders.

Capital of a Lantern, the covering by which it is terminated, either in a bell-shape, the form of a cupola, that of a spire, or in any regular figure whatever.

Capital of a Triglyph, the projecting band which surmounts the plain vertical area, or face, and which is disposed in a plane parallel to the said face. The capital of the triglyph of the Grecian Doric projects but a very small distance, and is not returned on the flanks, except at the angular triglyphs, and this only upon each face of the building; but in the Roman Doric, the capital of the triglyph projects more than that of the Grecian, and is returned with the same projection on the flanks as in the face.

CAPITOL, a celebrated rock, or hill, at Rome, whereon stood many ancient edifices, with the house of Romulus, &c.

Among the many celebrated edifices that formerly occupied this hill, the principal was the Asylum, erected by Romulus in order to people his new city. The house of Romulus was composed of canes, rushes, &c.; and every year the priests superstitiously repaired it with similar materials. Here was the Tabularium, or Archive, where were deposited the laws and consulta of the senate, and every other public act, written on tables of bronze. Vespasian repaired the Capitol, and had three thousand new tables made, the former having been defaced when the library and other buildings were destroyed by lightning. It is supposed to have stood where the arches and Doric columns are now seen, behind the Senators' Palace, towards the Campo Vaccino. Here was the Curia Calabra. Here also stood the house of Manlius, the defender of the rock, destroyed on account of the treachery of its master. The temple of Juno Moneta was built on its site. The number of temples on this hill was very considerable: some make them amount to sixty. But the great quantity of statues in marble, metal, silver, and gold, erected to heroes who had deserved well of the republic, causing great confusion, Augustus removed great part of them to the Campus Martius.

All these noble edifices, once the ornament of the mistress of the world, have fallen a victim to the ravages of time,

and the still more destructive plunder of invading barbarians. At first this hill was only accessible from the south; but after the Campus Martius was inhabited, another road was opened towards the north. The first among the moderns who promoted the decoration of the Campidoglio was Pope Paul III. who, after a design of Bonarrotti, constructed the spacious steps.

CAPREOLS, in Roman carpentry, the struts or braces of a trussed roof.

CARACOL, is used sometimes to denote a staircase in the form of a helix, or spiral.

CARAVANSERA, in the East, a large building, or inn, for the reception of travellers, and the lodging of caravans. It is usually a large square of buildings, with a court in the middle, surrounded with galleries and arches, under which runs a kind of banquette, or elevation, some feet high, where travellers rest themselves, and make their lodging as well as they can; their baggage, and the beasts that carry them, being fastened to the foot of the banquette. Over the gate there are frequently small chambers, which the caravanseraskier, or director, lets out at a very dear rate, to such as wish to be retired.

CARCASE, the work of a house before it is either lathed or plastered, or the floors laid.

Carcase, or Naked Flooring, that which supports the boarding above, for walking upon, and the ceiling below, by a grated frame of timber, consisting of three tiers of beams, called *joists;* the middle tier being transverse to the other two. The beams of the middle tier, called *binding-joists,* support the other two tiers: the beams forming the upper tier, called *bridgings,* or *bridging-joists,* support the boarding, and are frequently notched upon the binding-joists: the lowest row of beams, called *ceiling-joists,* are either framed into the binding-joists, with pulley or chase mortises, flush with the under edges of the said joists, or are notched and nailed to them below. When the floor is very much extended in both dimensions, another set of large beams, called *girders,* the whole depth of the three tiers, are introduced, for shortening the bearings of the binding-joists, which are mortised and tenoned into the girder on both sides of it. The under edges of the binding-joists should be so framed, as to be below the under side of the intermediate girder, about half an inch, to prevent the ceiling from cracking; and the girder must be furred, to range with the under edge of the ceiling-joists. The general scantlings of these timbers are as follow, viz., girders, 12 by 13 inches; binding-joists, 10 by 4; bridging-joists, 5 by $2\frac{1}{2}$; and ceiling-joists, 3 by $2\frac{1}{2}$. The distance which these timbers are commonly placed in the clear is as follows: the binding-joists from 4 to 6 feet, which is also that of the ceiling-joists; and the bridgings 11 or 12 inches apart. As the girders go the whole length of the room, they have no fixed bearing; when they extend to 20 feet and upwards, they should be trussed. When the breadth of a room extends to 30 feet and upwards, the girders should be framed like the truss of a partition, with an upper and lower beam, and with posts, braces, and struts: for this purpose, a sufficient depth for the floor should be allowed, from two to three feet. Girders should never be placed over openings, unless they be supported by strong arches. When a lintelled opening comes under the place where the end of the girder should be, the end of the girder must be changed to the nearest solid bearing, which will throw its direction into an oblique position. The wall-hold for girders in brick buildings, may be from 9 to 12 inches, and for binding-joists, 6 inches. In stone buildings, for girders, from one foot to two feet, according to the thickness of the wall, and for binding-joists, 9 inches. In thick walls there may be two rows of wall-plates.

Carcase Roofing, that which supports the covering by a grated frame of timber-work, consisting of three tiers of timber, parallel to each other, and to the sloping surface of the covering. The most general disposition of the timbers is the following: the first tier and support is a row of timbers, inclined to the pitch of the roof, supported at various points by other timbers, which, with the inclined timbers, form as many vertical frames, perpendicular to the sides of the building as there are inclined timbers: each frame is called a *truss:* the inclined timbers in the upper part of the truss are called *principal rafters:* the principal rafters support a set of horizontal timbers transversely, and parallel to each other, called *purlins:* the purlins support the third and last tier of timbers of the frame, transversely or parallel to the principal rafters: the timbers of the last tier are called *bridging,* or *common rafters.* The upper surfaces of the principals, those of the purlins, and those of the common rafters, are sometimes framed flush with each other, or in the same inclined plane, in order to save room, or to conceal more of the roof: in this way the purlins must be tenoned, and the principals mortised to receive them; the small rafters and purlins are also tenoned and mortised together. But the best and strongest mode of carcase framing is, to make the purlins bridge over the principals, and the common rafters over the purlins. The principals rest upon a horizontal piece of timber, on the wall head, called the *raising,* or *wall-plate:* when the purlins bridge over the principals, and the small rafters over the purlins, the small rafters rest at the bottom upon a piece of timber called a *pole-plate.* The manner of joining the timbers in carcase roofing and flooring may be seen in the article Carpentry; other particulars relative to roofing, may be seen under Roofing, Truss, and Boarding.

Sometimes the covering is only supported by purlins resting upon the principal rafters; in this case, the length of the boards is disposed parallel to the principal rafters; but this position does not give so great strength to the roof as that which is horizontal.

CARDINAL SCAPI, in Roman joinery, the stiles of doors.

CARINA, in Roman antiquity, a building in the form of a ship.

CARNEDDE, in British antiquity, heaps of stones; supposed to be druidical remains for confirming and commemorating covenants.

CAROLITIC COLUMN. *See* Column.

CARPENTER (from the French *charpentier;* formed from *charpente,* timber; or, probably, from the Latin, *carpentarius,* a maker of *carpenta,* or carriages), an artificer, whose business it is to cut, form, and join timber, for the purpose of strengthening and supporting various parts necessary in the construction of buildings.

Carpenter's Rule, is generally used in taking dimensions, and in casting up the contents of timber and artificers' work.

It consists of two equal pieces of box, each one foot in length, connected together by a folding joint: in one of these equal pieces there is a slider, and four lines marked at the right hand, A, B, C, D; two of these lines, B, C, are upon the slider, and the other two, A, D, upon the rule. Three of these lines, viz., A, B, C, are called *double lines,* because they proceed from one to ten twice over in the length; these three lines are all exactly alike, both in numbers and division. They are numbered from the left hand towards the right, 1, 2, 3, 4, 5, 6, 7, 8, 9, 1, which stands in the middle; the numbers then go on again to 10, which stands at the right-hand end of the rule. These numbers have no determinate value of their own, but depend upon the value you set on the unit at the left hand of this part of the rule; thus if you

call it 1, the 1 in the middle will be 10, the other figures which follow will be 20, 30, &c., and the 10 at the right-hand end will be 100. If the first, or left-hand unit be called 10, the middle 1 will be 100, and the following figures will be 200, 300, 400, &c., and the 10 at the right-hand end will be 1000; and thus, whatever be the value of the first unit, the second unit in the middle is always ten times greater; and whatever is the value of the first and second unit, the following numbers to the right denote so many times that value as the number expresses.

The fourth line, D, called the *girt line*, is a single line, proceeding from 4 to 40. Upon it are marked W G at 17·15, and A G at 18·95, the wine and ale guage points, to make it serve the purpose of a guaging-rule.

The use of the double lines, A and B, is for working the rule of proportion, and finding the areas of plain figures. And the use of the girt line D, and the other double line C, is for measuring of timber. On the other part of this side of the rule, there is a table of the value of a load, or 50 cubic feet, of timber, at all prices, from sixpence to twenty-four pence, or two shillings, per foot.

On the other side of the rule are several plane scales, divided into 12th parts, marked *inch*, $\frac{3}{4}$, $\frac{1}{2}$, $\frac{1}{4}$, &c., signifying that the inch, $\frac{3}{4}$ inch, &c., are each divided into 12 parts. These scales are useful for planning dimensions that are taken in feet and inches. The edge of the rule is divided into inches, and each of these inches into eight parts, representing half inches, quarter inches, and half quarters.

In this description, the rule is supposed to be folded; let it now be opened, and pull out the slider, you will find the back of it divided like the edge of the rule, so that altogether it will measure one yard, or three feet, in length. The slide is very useful in taking inside dimensions for any length not less than one foot, nor greater than three feet.

Some rules have other scales and tables upon them; as a table of board measure, one of timber measure, a line for showing what length for any breadth will make a foot square, also a line showing what length for any thickness will make a solid foot. The former line serves to complete the table of board measure, and the latter the table of timber measure.

The thickness of the rule is generally about a quarter of an inch; this face is divided into inches and tenths, and numbered, when the rule is opened, from the right-hand towards the left, 10, 20, 30, &c., to 100, which falls upon the joint. The other half is numbered in the same manner, and the same way. The scales serve for taking dimensions in feet, tenths, and hundredths of a foot, when the contents are found by decimals.

Carpenter's Square, a square, of which both stock and blade consist of an iron plate, of one piece; it is in size and construction as follows:—one leg is 18 inches in length, numbered on the outer edge, from the exterior angle, with the bottom of the figures adjacent to the interior edge: the other edge is 12 inches long, and numbered from the extremity towards the angle; the figures are read from the internal angle, as on the other side; each of the legs is about an inch broad. This implement is not only used as a square, but also as a level and measuring rule. Its application as a square, in taking measures, is so easy as not to require example; but its use in taking angles may be thus illustrated: suppose it were required to take the angle which the heel of a rafter makes with the back; apply the end of the short leg of the square to the point of the heel and back, with the edge of the square level across the plate; extend a chalk line from the ridge of the roof to the said heel-point, and the division on the perpendicular leg of the square which the line falls upon, will mark the inches, and show how far it deviates from the square in 12 inches.

Carpenter's Work, in the mensuration of artificers' work, includes the taking of the dimensions of every descriptlon of timber necessary in the construction of buildings, finding their contents, and valuing the same.

The works done by the carpenter, in the general construction of buildings, are the preparation of piles, sleepers, and planking, or other large timbers in the foundations, centerings to vaults, wall-plates, lintels, and bond-timbers, naked flooring, partitioning, roofing, battening to walls, ribbed ceilings to form vaulting for lath and plaster, &c. These are not necessarily used in the construction of every edifice: piling and planking, or other timbers used in the foundation, are only incidental, depending upon the insufficiency of the ground to be built upon; the remaining articles may be all used in the most substantial and elegantly constructed houses.

Large and plain articles, where a uniform quantity of materials and workmanship is expended, are generally measured by the square of 100 superficial feet.

Piles may be made at per piece, and driven by the foot run, according to their diameter, and the quality of the ground.

Sleepers and planking are measured and valued by taking the superficial contents in yards or squares.

Plain centering is measured by the square; but as the ribs and boarding are two different qualities of work, they ought to be measured and valued separately; one dimension of the boarding is taken by girting it round the arch, the other is the length of the vault.

Centering for groins should be measured and valued as common centering, but in addition thereto, the angles should be paid for by the foot run, over and above; that is, the ribs and boarding ought to be measured and valued separately, according to the exact superficial contents of each, and the angles by the lineal foot for workmanship in fitting the ribs and boards, and for the waste of wood occasioned by the operation. Wall-plates, lintels, and bond-timbers, are measured by the cubic foot, under the denomination of *fir-in-bond.*

Naked flooring may either be measured and valued by the square, or by the cubic foot, according to the description of the work, and the quantity of timber employed. In forming an idea of its value, it is proper to observe, that in equal cubic quantities of small and large timbers, the small timbers will have a greater superficies than the large ones, and therefore the saving will not be in a ratio with the solid contents; consequently the value of the workmanship will not follow the cubic quantity or said ratio. The difficulty of handling timbers of the same length increases with the weight or solidity, as the greater quantity requires greater power to handle it, and consequently a greater expenditure of time: and though the time may not be exactly in a ratio with the solid quantity, there will be no great difference, as the respective sections will not vary considerably in their dimensions; and as the value of the sawing upon a cubic foot is comparatively small to that of the work done by the carpenter, the whole value of labour and materials may be ascertained with sufficient accuracy where the work is uniformly of one description.

In naked flooring, where girders are introduced, they interrupt the uniformity of the work by mortises and tenons. In this respect, the price ascertained by the cubic quantity of the girders, would not be sufficient at the same rate per foot, as the other parts, not only on account of the great difference of size, but as it is cut full of mortises to receive the tenons of the binding-joists, it occasions a still greater

disparity in the quantity of workmanship. A correct method, therefore, of valuing labour and materials, would be to measure and value the whole by the cubic quantity, and allow an additional rate upon every solid foot of girders; or if the binding-joists were not inserted in the girders at the usual distances, a fixed price for every mortise and tenon, in proportion to their size, which would keep a ratio with the area of the end of the girder.

As the binding-joists are sometimes pulley or chase mortised, to receive the ceiling-joists, and sometimes notched to receive the bridging-joists over them, they ought to be classed by themselves, at a superior price per foot cube, or at an additional price for the workmanship, above that of common joisting: this should always be allowed according to the description of workmanship, whether the ceiling-joists be put in their pulley mortises and tenons, or the bridgings notched or adzed down.

Partitions may be measured by the cubic foot, but the sills, top pieces, and door heads, should be measured by themselves, according to the solid quantity, at an additional rate, because both the uniform solidity, and the uniform quantity of workmanship, are interrupted by them. In trussed partitions, the braces should be rated by the foot cube, at a superior price to that of the quartering, for the trouble of fitting the ends of the uprights upon their upper and lower sides, and for forming the abutments at the ends.

In roofing, all the timbers should be measured by the cubic foot, classed as the difficulty of execution, or as the waste occasioned, may require. Common rafters may be rated the same as joisting or quartering; purlins at a superior price, for the trouble of fitting or notching down the common rafters; the notching of the purlins themselves, upon these principles, should be valued at per piece or notch. The various parts of trusses should be arranged separately; the joggles should be paid for at per piece, including the tenons at the ends of the struts; the mortising tie-beams and principals, and making the tenons of the truss-posts, should likewise go together; and the mortising and tenoning at the ends of tie-beams and principals, in another class; strapping should be paid for according to the number of bolts. In all these matters, regard must be had to the size and description of the work; common or bridging rafter-feet at per piece.

Battening to walls is best measured by the square, according to the dimensions and distances in the clear of the battening.

Ribbed ceilings should be measured according to the cubic quantity, making a proper allowance for the great waste of stuff; the price of labour will be regulated by the description of the work, and also by the cubic quantity of timber.

Trimmers should be measured separately, at such a price as to include not only the mortises and tenons of the joisting inserted into them, but the tenons at their extremities, and the mortises of the trimming-joists, which are to receive them. In this way, it would be unnecessary to take any account of the tenons at the ends of the bridging-joists, or of the mortises in the trimming-joists to receive the ends of the trimmer.

It would be endless to enumerate the various methods of measuring each particular species of carpenter's work; the leading articles only are here observed.

As soon as the shell of a building is finished, that is, previous to the floors being laid, or the ceilings lathed and plastered, all the timbers should be measured, that no doubt may exist as to the actual scantlings of the timbers, or of the description of the workmanship.

In taking the dimensions, it must be observed, that all pieces which have tenons, must be measured to the extremities of the tenons. Principal timbers, as binding-joists and girders, go at least nine inches into the wall, or one-third of its thickness, if more than 27 inches.

In taking the dimensions of bond-timbers and wall-plates, the several laps must be added to the lengths. When there is a necessity for cutting out parallel pieces from the sides of truss-posts, as in king or queen posts, if the pieces cut out exceed $2\frac{1}{2}$ feet in length, and $2\frac{1}{2}$ inches in thickness, they should be deemed pieces fit for use; but their lengths should not be reckoned so long by six inches, as the saw can hardly be entered with less waste.

The boarding of the roof is measured by the square, according to the thickness and quantity of the boards, and the manner of jointing them. In measuring for labour and materials, the most accurate method is, first, to find the cubical contents, the price of the cubic foot, including the prime cost, carting, sawing, waste, and the master's profit; then add the price of labour, properly measured, in the same manner as for the journeyman. Labour and materials are variable, and have no relation whatever to each other; consequently they cannot be reduced to single tables. The value of the cubic foot may be calculated by having the prime cost of the load, or 50 cubic feet: for example, let it be required to find the price of a cubic foot, when the price of the load is £10.

	£	s.	d.
50 feet cube fir, prime cost	10	0	0
Cartage	0	5	0
Sawing	0	10	0
7 cube feet waste	1	8	0
	12	3	0
20 per cent profit on the above	2	8	7
Master's price per load	£14	11	7

Then as 50 cubic feet are to one cubic foot, so is £14. 11s. 7d. the price of 50 cubic feet, to the price of one cubic foot. Thus,

		£.	s.	d.
50 : 1 ::		14	11	7
		20		
		291		
		12		
	5,0)	349,9		
	12)	$69\frac{49}{50}$		
		5 9		

So that the price of the cubic foot wants only the fiftieth part of a penny to be 5s. 10d. This is the rate of the master's price for the fir, exclusive of labour.

The foregoing are the methods by which the various parts of workmanship should be analyzed, in order to discover a legitimate ratio of prices; but we regret to add, that no particular account of time has been kept, in which the execution of certain uniform portions of work have been done, and by which alone we are enabled to give accurate calculations. The method of lumping work by the square, is not to be depended on, in the general admeasurement of buildings, as the surface is not always of a uniform description of workmanship; thus, in hipped roofs, the greatest trouble is at the hips, in cutting and fitting the jack-rafters, which are fixed at equal distances thereon, and therefore such a price may be fixed upon the cubic quantity of hips and vallies, as will not only

pay for the workmanship in themselves, but also f,r the trouble of cutting and fitting the jack-rafters.

It is impossible to fix a proper rate, including both materials and workmanship, as the one may be stationary, while the other is variable. With respect to materials, the value of any quantity may be easily ascertained, whatever be the price per load; but the far greater difficulty lies in fixing proper rates of workmanship; however, admitting that the time of executing every species of work were known, there would be no difficulty in establishing certain uniform quantities, which would give the real value at any time; the following is a specimen of the several rates of workmanship, by which the prices may be regulated at any time, admitting them to be right for the present. Each rate consists generally of three places of decimals on the right side of the point, and sometimes an integer on the left side. This table shows also the customary methods of measuring.

To find the price of the common measure of any kind of workmanship, at any time.—Multiply the wages of the workman by the rate; then, whatever denomination the wages is per day, the integers of the product, if any, will be of the same denomination, and the decimals will be parts of the same.

Example.—The centering of cylindric vaults is 2.033 per square; now let the wages per day be 5 shillings, or 60 pence; then $2.033 \times 5 = 10.165$ shillings per square, and by multiplying the decimal parts by 12, we obtain the pence. Thus—

$$\begin{array}{r} .165 \\ 12 \\ \hline 1.980 \end{array}$$

1.980 penny, or very near two pence; so that the value of a square of centering is nearly 10s. 2d.

Again, suppose the wages to be 5s. 6d. per day, then $2.033 \times 5\frac{1}{2} = 11.181$ shillings, or 11s. 2d, nearly: and thus for any other example.

TABLE I.

CENTERING.

	Fixed per square.
For cylindric plain vaults	2.033
	per ft. super.
For groins	.057
For gauged brickwork	.073
For brick trimmers bridge-wise	.041
For coach-head trimmers	.057
	per ft. run.
For apertures	.02

TABLE II.

MISCELLANIES.

	Fixed per ft. run.
Fir-in-bond and wood bricks	.008
Fir-in-templets, lintels, and turning pieces	.025
Planing fir from the saw, per foot super	.017
Rebating fir up to 2 inches by $\frac{3}{4}$	.025
Rebating from 2 inches by $\frac{3}{4}$ to 3 inches by $1\frac{1}{4}$	.041
Single beading up to $\frac{3}{4}$ inch	.008
Single quirk beading from $\frac{3}{4}$ inch to $1\frac{1}{4}$	.012
Return beads to be paid for at a double rate.	

TABLE III.

QUARTER PARTITIONS.

	Fixed per square.
Common four inch	1.033
Five inch	1.113
Six inch	1.307
Six inch circular plan	1.888
Trussed frame with king-post	1.743
Trussed, both king and queen posts	2.226

TABLE IV.

NAKED FLOORING.

	Fixed per square.
Ceiling floor, framed, with tie-beams, binding, and ceiling-joists	1.355
Ceiling floor with tie-beams and ceiling-joists only	1.065
Ceiling-joists only	.646
Single framed floor, trimmed to chimney and well holes, less than 9 inches deep	1.355
The same, above 9 inches	1.646
The same, if trimmed to party walls, add extra per square	.388
Single framed floor, with one girder	1.936
Strutting to be paid for extra.	

Continuation of Table IV.

	Fixed per square.
Single framed floor-case and tail bays	2.130
For every extra-cased bay add per square	.484
Framed floors, with girders, binding, and ceiling-joists	3.581
Ground joists bedded	.775
Ground-joists bedded and framed to chimneys	.968
Ground-joists pinned down on plates, and framed to chimneys	1.065
	per ft. run.
Girders reversed and bolted	.097
Truss girder-braces 4 inches by 4	.194
If any of the above works be done in oak, add one-third.	

TABLE V.

ROOFS.

Common Shed Roofing.

	Fixed per square.
One story high	.968
Two stories	1.033
Three stories	1.113

Single Span Roofing.

One story high	1.065
Two stories high	1.113
Three stories high	1.210
If the above have purlins, add per square .194; or if the purlins be framed diagonally, add double, or .388	
Hips and valleys	.08
In *common kirb roofing*, add extra per square when one side is kirbed . . 194	
When three sides 357	
When four sides 516	
Girt roofing, with framed principals, collar beams and purlins	2.323
Framed with principals, beams, king-posts, purlins, and common rafters	3.484
If the principals and rafters are framed flush, and the purlins housed in, add .387 per square to the above.	

Continuation of Table V.

	Fixed per square.
Framed with principals, beams, king-posts, queen-posts, and common rafters, three stories	— .549
The same, four stories	4.84
	per ft. run.
Hips and valleys	.145
Hip, and ridge rolls fixed on iron	.048
Bedded plates to common span roofing	.008
Bedded plates to common span roofing, as above	.028
Diagonal and dragon pieces	.065
Angular ties and struts	.032
Rafter-feet and eaves-board	.032

TABLE VI.

GUTTERING.

	per ft. super.
One or $1\frac{1}{4}$ inch deal, and bearers, including 6-inch side layer board	.057
The same in kirb roofs	.073

TABLE VII.

FURRINGS OR BATTENINGS.

	per square.
If the stuff be $\frac{3}{4}$ inch by $1\frac{1}{2}$	.872
But if the stuff is to be cut out, add .146 per square.	
Battenings with quarters, 3 inches by 2	.92
Battening to quarters, 3 inches by 2, to window piers	1.855
If the battens be fixed to plugs, add .29 per square.	
When any of the above are circular on the plan, add half as much more.	

TABLE VIII.

BRACKETING, INCLUDING PLUGGING.

	Fixed per ft. super
To straight cornices	.089
To coved straight cornices	.065
If circular on the plan, add one half more.	
To groins in passages less than 4 feet wide	.162
To the same, above 4 feet	.121

CARPENTRY, the art of employing timbers in the construction of buildings.

The important and useful art to which the general name of carpentry is given, is so intimately connected with the comforts and requirements of man, in every stage of civilized society, that no apology can be necessary for the length to which our observations on it must necessarily extend. In a work especially devoted to architecture, it of course must occupy a prominent place; for carpentry may be considered of so great importance, that no man may pretend to be an architect who is not well acquainted with its principles and its practice. Carpentry may be divided into two grand branches—*Carpentry* and *Joinery*. The first includes the larger and rougher kinds of work, or that which is essential to the construction and stability of an edifice: and, generally, all the work wherein timber is valued by the cubical foot.

Joinery, (called by the French *menuiserie*, from *menu*, small, and *bois*, wood, or small wood employed in that art) includes all the interior finishings and ornamental work, and is generally valued by the superficial foot.

Carpentry itself is properly divided into three branches, viz., *descriptive*, *constructive*, and *mechanical*.

Descriptive carpentry shows the lines or methods for forming every species of work in plano, by the rules of geometry. To this branch of the art, sometimes called "finding," the celebrated Monze gave the name of *descriptive geometry*.

Constructive carpentry shows the practice of reducing the wood into forms, and joining the parts, according to the intention or design of the architect, and thereby forming a complete whole.

Mechanical carpentry shows the relative strength of timbers, and the strains to which they may be subjected by their arrangement and disposition.

In this article, after a few preliminary observations on what may be termed the "HISTORY" of carpentry, it is intended to give such definitions as may conduce to a comprehension of the theory and practice of the art, and then to show the progressive improvements made by the several English writers in carpentry; the various rules for forming the timbers, and for the individual operations, being shown under their respective heads. *See* particularly CONSTRUCTIVE, DESCRIPTIVE, and MECHANICAL CARPENTRY.

History.—This art is of such general and important use, that there can be no doubt of its being of the highest antiquity. Little of its history, however, has been transmitted to us from the ancients. Pliny and Vitruvius are almost the only authors whose writings on the subject have reached modern times; but as their observations are merely confined to the choice and felling of timber, they are of no use as to the constructive part, and only demonstrate that such an art existed.

The practice of carpentry in its rudest form must of necessity have commenced in the very earliest ages; for in the first attempts at the construction of the primitive buildings of those days, carpentry must have been brought into exercise. It is probable that the necessity of introducing the pediment roof, occasioned the first use of timber frames, and consequently the art of carpentry in building. The invention of the pediment roof is justly attributed to the Greeks; as the oldest buildings of this description are to be found in their country; they also appear to have used timber for other purposes, as in the framing of floors, and the construction of rustic buildings.

In warm countries, furnishing stone or marble, it is probable that the use of timber was not very frequent, and that it was confined to movable articles, where lightness was an essential quality; we must, therefore, not look to these climates for any traces of the art.

The next great people, in succession of time, to the Greeks, were the Romans, who seem to have employed timber for all, or nearly all, the purposes that the moderns are acquainted with. They not only constructed their roofs, but whole buildings, of timber: in Vitruvius we have a description of their manner of constructing the architraves of Tuscan temples, and of the foundation of arched ceilings and floors, in timber work. The Romans also used wooden cornices. The theatres and amphitheatres at Rome, and in different parts of Italy, were at first constructed of timber; as we read of the wooden theatre of Pompey, and the amphitheatre built of the same material, by Augustus, to exhibit the shows on account of the victory at Actium. The roofs of the Roman buildings were not always concealed; the timbers were sometimes exposed, and in magnificent buildings they were gilt, as in the basilica of St. Peter, erected by Constantine; sometimes they were encrusted with bronze.

Though circumstances require certain dispositions of timbers in a building, the timbers will still admit of infinite decoration, without injury; and sometimes so much as at first view to conceal the principal use. In the middle ages, carpentry partook of the style of building called *Gothic;* the roofs were pitched very high, but were frequently defective, on account of the want of tie-beams. which were omitted in order to obtain more lofty ceilings; height being one of the predominant features of this species of architecture.

Carpentry has been cultivated by the modern Italians. Serlio, in his first book, exhibits a construction for naked flooring, with timbers shorter than either of the dimensions of the area to be covered; in the fourth book he shows some very curious and strong methods of framing doors, according to the principles of trussed work; and in the seventh book, he has some very good forms for the trusses of roofs. The wooden bridges of Palladio are most excellent examples.

Among the French, the construction of wooden domes has been improved by Philibert Delorme, and Moulineau; and the centerings of arches and bridges by Perronet.

In England, the very curious construction of naked flooring, exhibited in the works of Serlio, has been demonstrated and improved by Dr. Wallis, and carried into execution, in the theatre of Oxford, by Sir Christopher Wren, who also designed the wood trussing of the dome of St. Paul's, and contrived a very curious scaffolding, which supported itself without anything below it, for the purpose of building and painting the interior dome. The art of carpentry has been much cultivated of late years in England, so that it has now begun to assume a scientific form. In accuracy and celerity of execution our workmen are unequalled.

Of late years the improvements in the manufacture of iron, both *cast* and *wrought*, have caused the introduction of that material into buildings in every variety of form—as *girders*, *beams*, &c. The floors, and sometimes even the roofs of those intended to be secured from fire, have been constructed of iron; and iron hooping is now used instead of bond-timbers in walls. The use of this material, however, as a substitute for wood, does not change the principle, as both materials are affected by the same gravitating laws.

The operations to which timber is subjected, from the time of its arrival in the carpenter's yard, in its natural state, to the period of its final employment in a building, may be classed under two general heads; as, those which relate to individual pieces, and those that relate to their connection with others.

Under the first head is the pit-saw, by which whole pieces of timber are divided, and reduced into scantlings. This term (from the French, *enchantillon*) means the dimensions in breadth and thickness, without respect to the length.

Planing is the operation of reducing the wood to a smooth surface, by means of an instrnment called a *plane*, which consists of a chisel fixed in a frame, serving at once as a handle and a regulator to the edge, which cuts the wood in thin shavings as the plane is moved to and fro by the workman. The operations of the plane, besides that of reducing timber to a uniform surface, are those of grooving, rebating, and moulding: the latter not being necessary in carpentry, we shall only describe the former two: Grooving is the reducing a piece of timber below the surface, so as to take away a prism, and thereby leave a channel consisting of two surfaces of equal breadths, and another surface, of equal breadth, joining the other two, parallel to the surface from which the recess is made, generally forming two individual right angles.

Rebating is the reducing of a piece of timber, by taking away a prism at the angle, so as to leave only two sides, each of a parallel breadth, forming an internal angle, generally a right angle: so that in grooving and rebating, the groove or rebate is always less than the original depth of the stuff or piece out of which it is formed. The latter operation is particularly used in door-cases and the frames of casement-windows; the rebate forming a kind of ledge for the door or casement to stop against.

The implements which the carpenter has occasion to employ in the several operations, will be seen under the head Tools.

The principal operations, after the pieces are formed, consist in the joining of timbers: two pieces of timber may be joined so as to form either one, two, or four angles, oblique or right. A notched joint is formed by cutting out of the thickness of each piece, a part in the form of a parallelopiped; so that when the two pieces are joined, the substance left at the reduced thickness of the one piece, fills the excavation of the other, as far as it goes into its depth. If the thickness of the part left be equal to that of the part taken away in each piece, and the thickness of the part left of the one piece be equal to the thickness of the part left of the other piece, the joint is then said to be halved. In making one angle, the excess or excavation is formed at the end of each piece, and consists of two plane surfaces, one perpendicular, the other parallel to the two opposite faces, and in the plane of the angle. In forming two right angles, one piece must, of course, project on both sides of the other, and the other only on one side; the excavation or recess made in that which projects on both sides, consists of three plane surfaces, one being parallel, and the other two at right angles to the faces; the excavation or recess made in that which projects on one side, consists of two plane surfaces, in the like positions. In forming four right angles, the notch of each piece consists of three sides, two of which are at right angles, and the other parallel to the faces. One piece of timber may also be joined to another, so as to form only one or two adjacent angles, by notching one piece on three sides at the ends, and so forming a projecting prism, called a *tenon*, the sides of which are respectively parallel to the sides of the piece, and by excavating the end of the other piece, to receive the tenon, which is made to fit exactly. The two pieces thus formed at one or more angles to each other, may, if found necessary, be fixed by means of wooden pins, or nails, spikes, screws, bolts, straps, or other metal fastenings.

The two celebrated Italian authors, Serlio and Palladio, have given designs in carpentry. The British authors who have written on this useful art, are Godfrey Richards, at the end of his *Translation of the First Book of Andrew Palladio*, third edition printed 1676; Moxon's *Mechanical Exercises*, second edition printed 1693; Halfpenny's *Art of Sound Building*, printed 1725; *The Carpenter's Companion*, by Smith, printed 1733; *Ancient Masonry*, by Batty Langley, printed 1733; *The British Carpenter*, by Francis Price, printed 1735; *The Gentleman's and Builder's Repository*, by Edward Hoppus, printed 1738; *The Builder's Complete Assistant*, by Batty Langley, printed in 1738; *The Builder's and Workman's Treasury*, by Batty Langley, printed in 1741; *The Builder's Jewel*, by the same author; *The London Art of Building*, by William Salmon, the third edition, printed in 1748; *The British Architect*, by Abraham Swan, second edition printed in 1750; *Designs in Carpentry*, by the same author, printed in 1759; several pieces of carpentry, in *A Complete Body of Architecture*, written by Isaac Ware, published in 1768; *The Carpenter's and Joiner's Repository*, by William Pain, printed in 1778; *The Carpenter's Pocket Directory*, by the same author, printed in 1780; *The Golden Rule*, by the same, printed in 1781; *The British Palladio*, by the same, printed 1788; *The Practical Builder*, by the same author; *The Practical House Carpenter*, by the same author, printed in 1791. The following are productions of the Author of the present Work: *The Carpenter's New Guide*, in 1792; *The Carpenter's and Joiner's Assistant*, printed in 1792. Likewise, the various articles on carpentry, in Rees' *Cyclopædia; A Treatise on Carpentry*, in the *Edinburgh Encyclopædia;* and a treatise on the same subject, in his *Mechanical Exercises.* A long article on Carpentry, in a Supplement to the *Encyclopædia Britannica*, was written by Professor Robison, of Edinburgh; and an article on Carpentry, in *A Course of Lectures on Natural Philosophy and the Mechanical Arts*, by Thomas Young, M. D., late Professor of Natural Philosophy in the Royal Institution of Great Britain.

We shall here give extracts from these authors, in order to mark the various methods and progressive improvements in the scientific and practical parts of carpentry, particularly that part which relates to geometrical description.

Godfrey Richards, in his general title, at the end of the translation above referred to, writes thus:

"*Of Roofs.*—Rules and instructions for framing all manner of roofs, whether square or bevel, either above or under pitch, according to the best manner practised in England.

"Also to find the length of the hips and sleepers, with the back or hip mould, never yet published by any architect, modern or antique; a curiosity worth the regard, even of the most curious workman; exactly demonstrated in the following rules and designs, by that ingenious architect, Mr. William Pope, of London.

"Having raised the walls to their designed height, and made the vaults, laid the joists, brought up the stairs, and performed all those things spoken of before; we are now to raise the roof, which embracing every part of the building, and with its weight equally pressing upon the walls, is a band to all the work; and besides defends the inhabitants from rain, from snow, from the burning sun, and from the moisture of the night; adds no small help to the building, casting off from the walls the rain water, which although for a while it seems to do but little hurt, yet in process of time is the cause of much damage. The first men (as saith Vitruvius) built their houses with flat roofs, but finding that thereby they were not defended from the weather, they (constrained by necessity) began to make them ridged (that is to say) raised in the middle. These roofs are to be raised to a higher or lower pitch, according to the country in which they are; wherefore in Germany, by reason of the great quantity of snow that falls there, they raise their roofs to a very great pitch, and cover them with shingles, which are small pieces of wood, or of thin slate or tiles; for if they should raise them otherwise, they would be ruined by reason of the weight of the snow. But we, who dwell in a more temperate country, ought to choose such a pitch as may secure the building, and be of a handsome form: therefore we divide the breadth of the roof into four equal parts, and take three, which makes the most agreeable pitch for our country, and is the foundation for the raising of any manner of roof, whether square or bevel; as appears in the following designs and descriptions."

"*The manner of framing a floor, with the names of each member.* (*See* Carpentry, *Plate* I. *Figure* 1.

"1. The thickness of the wall, and lintel or wall-plate; and if it be in timber-work, then a bressummer.

"2. The summer.
"3. Girders framed into the summer.
"4. Spaces between the joists.
"5. Joists.
"6. Trimmers for the chimney way.
"7. Trimmers for the staircase, or well-hole for the stairs."

Figure 2.—"*Of the Design.*

"A A The breadth of the house, cantalivers, cornices, and eaves.

"A B The length of the raftings and furrings, which ought to be three-fourths of the breadth of the house, A A.

"The principal rafters to be cut with a knee (as in the Design) that they may the better support themselves and the burthen over them, upon the upright of the wall, and also secure that part from the dripping in of the rain, which otherwise would happen if the rafters were made straight and furred.

"The beams to the roof, or girder to the garret floor, ought to project without the work, as far as the furring or shredding, which is the projecture of the cornice.

"This manner of framing the roof will be useful from 20 to 30 feet, or thereabouts.

"1. Ground plate.
"2. Girder, or binding interduce, or bressummer.
"3. Beam to the roof, or girder to the garret floor.
"4. Principal post, and upright brick wall.
"5. Braces.
"6. Quarters.
"7. Interduces.
"8. Prick-post, or window-post.
"9. Jaumes, or door-posts.
"10. King-piece, or joggle-piece.
"11. Struts.
"12. Collar-beam, strut-beam, wind-beam, or top-beam.
"13. Door-head.
"14. Principal rafters.
"15. Furrings, or shreddings.
"16. Ends of the lintels and pieces.
"17. Bedding, moulding of the cornice over the windows, and space between.
"18. Knees of the principal rafters, which are to be of one piece.
"19. Purline mortises."

Figure 3. "*Design of the gable end, or roof.*—Let the whole length of the gable end, or roof, A A, be 20 feet, divide the same into four equal parts; take thereof three for the length of the principal rafter, A B, and placing that perpendicular from the point C, to the point D, beget the length of the sleeper A D, which will be 18 feet. And the length of the dormer's principal rafter, from A to E, when laid to its pitch upon the back of the principals, will reach to the level line F B, or top of the principal rafter; and this is a general rule for all breadths.

"1. Summer, or beam.
"2. King-piece, crown-post, or joggle-piece.
"3. Braces, or struts.
"4. Principal rafters.
"5. The sleeper.
"6. Purline of the dormer.
"7. Principal rafter of the dormer.
"8. Single rafter of the dormer, standing on the sleeper and purline.
"9. Point of the sleeper.
"10, 11. The thickness of the wall and lintels, or wall-plates."

Figure 4.—"*Of the Italian or hip roof.*

"A A The breadth of the roof, being 20 feet.

"A B The length of the sleepers or hips, being 18 feet, which is proportionable to the breadth of the house.

"E D The height of the roof perpendicular.

"C D The length of the hip, and the angle which it maketh upon the diagonal line, which is showed by the pricked line G, from F to C.

"1, 2. The wall and lintels.
"3. Dragon-beam for the hip to stand on.
"4. Beam on summer, wherein the dragon-beams are framed.
"5. King-piece, or crown-post.
"6. Struts or braces from the crown-post to the hip-rafter.
"7. Hips, as they make the angle equal to the breadth of the house.
"8. Hips, as they make the angle in the diagonal lines from corner to corner.
"9. The additional length which the hips make upon the diagonal lines, more than the breadth of the house."

"*Of flat roofs.*—(CARPENTRY, *Plate* II. *Fig.* 1.)—Within a camber-beam and rafters joggled in, whose weight lieth not chiefly in the middle, and may be so made, that, without hanging up the beam, the principals may discharge the weight; and how drips may be made to walk on.

"1. Camber-beam.
"2. Principals joggled into the camber-beam.
"3. The place where the principals are joggled in.
"4. Puncheons, or braces.
"5. Drips to walk on, and may be made with the less current, that the roof may be made the more pitch, for the strengthening thereof: and may be made higher or lower, according to the building and discretion of the architect.
"6. Battlement."

Figure 2.—"A flat roof with a crown-post, or king-piece."

Figure 3.—"*Of the hip roof.—Instructions to find the length and back of the hip, so as it may answer the side and the end of the perpendicular line of the gable end, the two skirts, the side of the roof in plano, or lying in ledgment with the hip and gable end, the diagonal and perpendicular lines being laid down proportional to any breadth or length, by which the most ingenious may serve himself, and an ordinary capacity (already acquainted with the use of the ruler and compass) may plainly demonstrate all the parts of a roof, whether square or bevel, above pitch or under pitch, by lines of proportion, as may appear in the Design following:*—

"Suppose the roof 20 feet broad, and in length 30, 40, or 50 feet, more or less. Let A B C D be the sides and ends of the said roof, one end to be hipped, the other a gable end; draw the lines A B C D the breadth and length of the roof; then draw the gable end A B E, whose sides or principal rafters being three-fourths of the breadth of the house, then draw the perpendicular line E F, the height of the gable end, which line is of general use to level the ridge of all roofs; and if the other end be hipped, as in the Design, D C G, then it serves to find the length of the hip, and the back of the hip, so that it may answer both sides and ends of the roof; always observing, that the middle of the breadth of the house is as I H; then draw the line K L N through the centre I, which will make right angles to the line E F H G, both in bevel and square houses. Then extend the line A B, on both sides to O, being the length of A E, or E B, the length of the principal rafters, or three-fourths of the breadth of the house

So will O N and O K make the length of the ridge I F; and K D and C N, the two skirts.

"*To find the length of the hip.*—Draw the diagonal line D I and I C, over which the hip is to hang when in its due place; then take the perpendicular line E F, and place it from the point I to P P, perpendicular to the diagonal or base lines D I and I C, at I; so is I P and I P, the pitch of the hip, equal to the gable end, E F: and when erected, will hang perpendicular to the point I; then take P D, the hypothenuse of the triangle D I P, and C P, the hypothenuse of the triangle C I P, placing them from D to G, and C to G gives the length of the hip D G C, and when laid to their pitch, will all meet perpendicular to the point I.

"*To find the back of the hip, so that it may answer both sides and ends of the roof, whether square or bevel.*—Lay the ruler from the point L to the point H, and from the point H to M, and mark where it cuts the diagonal lines D I and I C at Q Q; then set one foot of the compasses on the point Q, and extend the other foot to the hip lines D P and C P, at the nearest distance; with that, mark the point R upon the same diagonal lines; then draw the pricked lines L R H and H R M, which make the back of the hip for the two corners of that roof.

"This rule serves for all roofs, whether over or under pitch."

Figure 4.—"*Of roofs bevel at one end, and square at the other; the gable end square, and the bevel end hipped.*

"Suppose the breadth of the roof to be 20 feet, the length more on one side than on the other, as in the Design, A B C D, then draw the gable end, A E B, whose sides, from A to E, and from E to B, are three-fourths of the breadth of the house, or the length of the principal rafters; then draw the perpendicular, E F, the height of the roof from the floor; and, if kneed, then from the top of the knee, as in the design of a kneed rafter, before-going.

"The sides of the roof, which make the ridge G H I K, to be drawn as described in the foregoing design.

"Divide the breadth of the roof in two equal parts, as F L Q, then take the distance L N, which is the half breadth of the house, and make it parallel to C Q D, as M L M, and L will be the point whose perpendiculars, O T, will meet the principals, rafters, and hips."

"*To find the length of each hip, distinct one from the other.—Of the longest hips.*—Draw the diagonal line L C, and take the height of the gable end, E F, and place it perpendicular to L C, at O; so have you the height of the roof perpendicular from O L, equal to E F, the gable end; and the line O C will be the length of the hip-rafter, which will be equal to C H, the skirt for that side of the hip, and C P the side of that hip end.

"*To find the back of the longest hip,* C O.—Lay the ruler from the point M to Q, and mark where it cuts the diagonal line at R; then set the foot of the compasses at the point R, and extend the other foot till it touch the line C O at the nearest distance; then make it touch the diagonal line at S, then draw the lines M S Q, which is the back of the hip for that corner of the roof.

"*To find the shortest hip.*—Draw the diagonal L D, and take E F, the perpendicular of the gable end, as before, and place it from L to T, perpendicular to L D; then draw the line T D, which is the length of the hip for that corner, and is equal to the skirt, D I, and the side of that hip, D P, which, when erected, will meet with the other principals, perpendicular to the point L.

"*To find the back of the hip.*—Lay the ruler from the point Q to the point M, and mark where it cuts the diagonal line L D, at V: extend the compasses from the point V, to touch the line T D at the nearest distance, and carry that distance on the diagonal line to the point W; then draw the pricked lines M W Q, which will make the back of that hip fit for that bevel corner.

"And this rule serves for all bevel roofs, whether over or under pitch."

Figure 5.—"*Of a roof bevel at both ends, and broader at one end than the other.*

"A B C D. The length and breadth of the house.

"E F G. The length of the rafters, or pitch between the widest and narrowest ends, about the middle of the house, to stand over the pricked line T T, for the foot F to stand, on the one T, the foot G to stand on the other T.

"H H. The point of the two hip ends, when brought to their due place, will be perpendicular to P P, and will meet the sides I K, L M, over the points P P.

"O, O, O, O. The points of the perpendiculars, and length of the hips, from A B C D.

"Q, Q, Q, Q. The backs of the hips, or hip-mould to each corner.

"R, R, R, R. The points to find out Q, the point for each back.

"S S, S S. The lines representing half the breadth of the house, parallel to each end.

"T T. Representing the middle of the house.

"Notwithstanding the bevel ends, you may place your beams for your principal rafters to stand on a square, or so near a square as may be, or between both, as from the ends of the pricked lines I K, L M, bringing the outside of them straight under P P, which will be more handsome for the house in the inside, although it bevels outward."

The foregoing descriptions and diagrams contain all that is said on carpentry by Godfrey Richards; we shall now add a few observations.

In the explanation of *Figure* I, *Plate* I., CARPENTRY, we have the names of the several timbers which constitute a floor, and the manner in which they are disposed. In this explanation, and the plan which accompanies it, we find girders, summers, and bressummers. The summer runs parallel to the front of the building; another piece of timber is placed in the front, parallel to, and in the same level with the summer; if the front timber terminate the apertures at their height, and the wall be of brick, this timber is called a *lintel;* but if the lower side of the timber do not terminate the windows, it is called a *wall-plate.* If the front wall is constructed of timber-work, then the level piece of timber in the floor, and in the front of the house, is called a *bressummer*, which in modern carpentry, when employed in the same office, still retains that name; and hence the term *bressummer* signifies a summer in the breast or front of the building. The use of the summer was to support the ends of the adjacent girders; and the bressummer was not only to support the end of the one girder, but to tie the front together. In the present construction of houses, summers are not employed. In old carpentry, the girders supporting the joisting were sustained at their ends by the summers and bressummers, lintels, or wall-plates. In modern carpentry, the girders are sustained by opposite walls, upon plates or lintels, and are still used over every extensive bearing to support the joisting.

In modern timber-buildings, and partitions, the same names are still used for the same things, as in old carpentry, wherever the things themselves are employed, except in a few instances, viz., the *interduces* are now called *interties;* the middle beam of the roof went by several names, as *collar-beam*, *strut-beam*, *wind-beam*, or *top-beam;* but of

these names, only that of *collar-beam* is retained. At present we have no *kneed-rafters*, therefore neither furrings nor shreddings are necessary as in *Figure* 2; the *prick-posts* are now called *jamb-posts*, *window*, or *door-posts*; the vertical timber hanging from the vertical angle of the roof, and supporting the principals, went formerly under the names of *king-piece*, *crown-post*, or *joggle-post*; but now it retains only the name of *king-post*. The nomenclature employed in London and its vicinity is here alluded to.

The timbers in the internal angles, at the meeting of the two inclined sides of a roof, were formerly called *sleepers*, but now they are termed *valley-pieces*, or *valley-rafters*, see *Figure* 3; in which may be seen also a method of finding the length of the hip, without making any plan of the roof.

Plate II. *Figures* 3, 4, 5, show the manner of finding the lengths and backs of the hips, as at present. The discovery of this principle is generously ascribed to Mr. Pope, of London, by the author now quoted.

Thus much for the work published by Godfrey Richards.

The carpentry published in Moxon's *Mechanical Exercises*, contains nothing more than the names and applications of timbers, which are the same as those described by Godfrey Richards.

In *The Art of Sound Building*, Mr. Halfpenny shows the methods of tracing the angle-brackets of coves, regular and irregular groins, the common ribs in each return being of one common height.

The following specimens will show what has been done by this author. He likewise shows how to find the arch for the aperture of a window, of a given width and height so as the angles may be in vertical planes, according to legitimate principles; but he does not, in any instance, show the method of beveling the edge of the angle-ribs, so as to range with ribs fixed in the returns.

Plate III. *Figure* 1. "*To find the angle or mitre-bracket of a cove.*—First, draw the base A B of the regular bracket, and from A draw A D, perpendicular and equal to it, and draw the line D B, and continue the line D A to C, so that A C be also equal to A B; then extending your compasses from A to B, and setting one foot in A, with the other describe the arch, or quarter of a circle C B, and from the point D draw D F, perpendicular to D B, and equal to D A, or A C, and another as B E from B, likewise equal to D A, and draw the line F E, which will be parallel to D B. This being done, divide A B into a number of equal parts, not exceeding two inches and a half, and through the divisions of them draw lines parallel to A C, to touch the arch C B, which continue out to the line D B, and this line will be divided likewise into the same number of equal parts as A B is. Lastly, from the divisions of the line D B, draw lines parallel to D F, and in each of them, from D B, lay off its respective parallel (from A B to the arch B C) and at the points whereat they end, stick small nails, or pins, and take a thin lath, and bend it round the nails, or pins, observing that it touches them all, and with a pencil, or anything else proper to make a mark, describe the arch F B round the edges of the lath; and this is the arch for the angle or mitre bracket."

Figure 2. "*If the lesser arch of an irregular groin be a given semicircle, it is required to form a larger one (not a semicircle) so that the intersection of those two arches shall beget, or make the arch-line of the angle to hang perpendicular over its base; as also to draw that arch-line of the angle.*—First, draw the lines A B and C D, to represent the walls from whence the arches spring, and draw the line C B, and on the line A C describe the semicircle A E C, and divide A C into any number of equal parts, from whence draw parallel lines to C D, to touch or come to the arch A E C, and if these parallels are continued out to the line C B, they will divide it into the same number of equal parts as A C is; and if from each of the divisions of this last line parallels to A C are drawn, they will divide the line A B into the same number of equal parts as A C, or C B, is divided into. This being done, continue A C to I, so that A I be equal to E *f*, and continue D B to K, so that K B be likewise equal to E *f*, or A I, and draw the line I K. Moreover, at the points C and B raise the perpendiculars C N and B O to C D, each of the same length as E *f*, or A I, or B K, and draw the line N O. Lastly, from the divisions of A B, draw parallels to A I (that is, continue the parallels drawn from the divisions of the line C B to the line I K) and from the divisions of C B parallels to C N. Then set off the heights or lengths of each of the parallels in the semicircle A E C, upon the correspondent parallels to A I and C N, and stick in nails whereat they terminate; and if a lath be bent round them, so as to touch them all, and a pencil be moved round the edge of it, the arches A H B and C M B will be found; which was required to be done.

"*Note.*—The pricked lines in this, and all other examples of this kind, show that one parallel line has a relation with the other. For example: the lines *f* E, *g* H, *l* M, are all equal to one another; so that if the three arches A H B, A E C, and C M B, were raised perpendicularly upon the lines A B, A C, and C B, and a line drawn from H to M, and another from M to E; then would the line M H be parallel to, and directly over the pricked line *l g*. In like manner, the line E M would be parallel to, and directly over the pricked line *f l*. Understand the same of the other parallels and pricked lines in this figure, and any others of the like nature."

Figure 3.—"*Having one centre given for an unequal-sided groin, to form the other, so that the intersection thereof shall produce the angle, or mitre-arch, to hang perpendicularly over its base; and, moreover, to draw the curve thereof.*—Draw the lines A B and B D, and D C and C A, each equal to one another, to represent the walls from whence the arches spring, and on the line A B describe the given arch A F B. This being done, divide the line A B into any number of equal parts, from whence raise perpendiculars to A B to touch the arch A F B, and draw the diagonal lines A D and B C. Then take the line E F, and set it perpendicular to the lines A C, A D, C D, C B, B D, from A to O, from A to I, from C to P, from C to S, from C to L, from D to K, from D to T, from D to V, and from B to M, and from B to Z, and draw the straight lines O P, I K, S T, L M, and V Z. Now divide the base lines B D, D C, C A, A D, and B C, each into the same number of equal parts as A B is divided into, and from the points of division draw parallel lines to touch the lines O P, S T, V Z, L M, and I K. Then take the lengths of the perpendiculars to A B, drawn to touch the given arch A F B, and set them off in the correspondent parallels drawn from the points of division of the several bases upwards, and the arches B *y* D, D *v* C, C *q* A, A *h* D, and C *n* B, will be described as in the foregoing examples (*Figures* 2 and 3) whose heights *x y*, *w v*, *r q*, *g h*, and *g n*, are each equal to E F, as likewise all the other correspondent heights, from the bases to the curves that are formed.

Figure 4.—"*The arch line of a large ceiling, or vault, supposed to be semicircular, being given: how to form the curve of a lesser arch, that shall intersect the side thereof, to give way for doors or windows, so that their intersection shall produce the groin to hang perpendicularly over its base; as also to form the curve-line thereof.*—First, draw the lines A B, B D, D C, and C A, to represent the walls from whence the arches spring, and describe the two given semicircular arches A O B, C L D, and in the line B D set off the span of the intersecting arch from *v* to *t*. This being done, set off the height you design to raise the lesser arch *v z t* from *g* in the line A B,

perpendicularly to touch the arch in *h*, and from *v* to *r*, and *t* to *u*, and draw the line *r u*, which halve in the point *z*, and draw the line *z y*, parallel to *v r*, or *t u*. Then strain a line, or lay a straight rule from *h* through *g*, towards *x;* as also from *z* through *y*, towards *x*, and these two lines will cut one another at *x*, from whence to the points *v* and *t*, draw the lines *x v* and *x t*. Now set off *g h* perpendicular to *x t* from *x* to *w*, and from *t* to S, and draw the line S *w*, and divide *g* B into any number of equal parts at pleasure from the divisions of which, draw perpendiculars to *g* B, to touch the arch A O B between the points B and *h*, and divide *v y* and *y t*, the halves of the base *v t*, each into the same number of equal parts as *g* B, is divided into: as likewise the base *x t*, and from the points of division draw parallel lines to touch the lines *u r* and S *w*. This being done, take the lengths of the lines that were drawn from the points of division of *g* B, perpendicularly to touch the part B *h* of the arch A O B, and set them off in the correspondent parallels from *y v* to *z r*, and from *y t* to *z u;* as likewise from *x t* to *w* S. Then, if at the extent of each line, as you set it off in the parallels, you stick in nails, as in the foregoing examples, and bend a thin rule about them, you will describe the sought arches *v z t* and *w t*, whereof *v z t* is the true intersecting arch, and *w t* the curve line of the groin that is correspondent thereto.

"After the very same manner the arches *k m z* and *k p* are drawn."

In his explanations of the diagrams, he is tolerably intelligent; but he has departed from truth and reason in the two following problems:—

"*The arch of a round tower, or any other circular building, being given, wherein a semicircular window is to stand, how to find a centre, so that the mason or bricklayer shall twin their arches thereon without crippling them.* (See *Plate* III. *Figure* 5.)

"First, draw the arch A F B, from the centre E, to represent the arch line of the wall, and set the width of the window from D to C, which halve at H, and draw the line L M, which halve at N; from whence describe the semicircle L O M. This being done, divide the semi-diameter L N into any number of equal parts, from the division of which, draw parallel lines to O N, the arch of the quadrant, which parallels continue out to divide the arch F C into the same number of parts as L N is; and from the points of division in the arch F C draw perpendiculars to the parallels, each equal in length to the correspondent parallel of the quadrant L O; and from the points of the divisions of the line H C (made by continuing out of each of the aforesaid parallels) draw right lines to the extreme points of the aforesaid perpendiculars, as from G to H. This being done, if the line G H be laid off in the parallel O N, continued out from H to I, and the rest of these lines last drawn be laid off in the respective continuations of the parallels, the extreme points of these lines being joined, will form the curve C I; which, when set in its due position, will hang perpendicular over the arch C F, having its points coinciding with the extremities of the perpendiculars drawn from the extremities of the perpendiculars drawn from the divisions of the arch C F."

Figure 6.—"*The centre whereon the arch of a bow-window is turned being given, how to find another centre that shall answer parallel to it, according to the upper edge of the surface of the arch.*—First, describe the arch B K C, according to the directions laid down in the last problem, and set the width of the flat surface of the arch from B to A, and from C to D; and draw the lines A D, B C, and halve them at F and E, from whence draw a perpendicular of a length at pleasure to H. Then in any convenient place (*Figure* 6, No. 2) draw a line at pleasure, as from A to G, and from A draw to A G the perpendicular A F. Then take E I, in No. 1, and set it from A to B, No. 2, and F I from A to C. This being done, take the semi-diameter B E, or E C, No. 1, and set it from A to D, No. 2. Also, take A B, or C D, and set it from D to E, and draw the line E C, which set in the line E H, from F to *g*. Again, take the width of the flat surface of the arch A B, or C D, and set it in the line E H, from K to 7, and divide the remainder from 7 to *g*, into seven equal parts. Also, divide the arch B K, into seven equal parts. Then take K 1, in the line E H, between your compasses, and setting one foot in 1, with the other strike the arch 1 at pleasure: then take K 2, and strike the arch 2: also take K 3, K 4, K 5, and K 6, severally, and strike the arches 3, 4, 5, and 6. When this is done, open your compasses, and divide from A to *g*, keeping the points of them on those arches, till you have gotten seven equal distances from A to *g;* at the points of which, if nails be stuck in, and a thin rule be bent round them from A to *g* along the edge thereof the arch A *g* may be drawn. And in like manner may the arch D *g* be drawn."

This description is so far intelligible, that we perfectly understand his geometrical process; but it is so void of truth, that no geometrical reasoning can be applied, unless it were to prove the contrary of his assertion: the arch which would be required to stand perpendicularly over such a plan upon a semicircular centre, would not be in the same plane, which is the case with the one he has found, and asserted to be right.

In the construction of the ribs of niches for plastering, he is extremely obscure, and takes only the most common and easy cases; such as might occur to every one, even to those who are not much in the habit of thinking, as the reader will observe in the following quotations:—

Figure 7.—"*How to form a semicircular niche with ribs, as is usual when it is to be plastered.*—First, describe the semicircular plate A C B, as also the semicircular front rib A D B, equal to it, and fix the plate A C B level in the place where it is to continue, and upon it set the front rib A D B perpendicular on A B. This being done, describe the quadrantal ribs D C, D E, D F, D G, and D H, each equal to A D or B D, and place them about $8\frac{1}{2}$ inches from one another, on the plate A C B, as at C, E, F, G, and H, so as to meet in one point, at D, on the crown of the front rib A D B; and thus is one half of the work finished. And after the same manner may the other be done."

Figure 8.—"*How to form an elliptical niche, with ribs for plastering.*—First, describe *Figure* 8, No. 1 and 2, *k n m* being a semi-ellipsis, representing the plates whereon the ribs stand, and being equal to A D B, or A *e* B. The pricked lines L *n*, L *o*, L *p*, L *q*, L *r*, and L *m*, represent the base lines of the ribs *e* D, *f* D, *g* D, *h* D, *i* D, and B D; so likewise do the lines S *t*, S *u*, S *v*, S *w*, S *x*, and S *y;* and the perpendiculars *a t*, *b u*, *c v*, *d w*, *e x*, and *f y*, do represent the rising of the ribs *e* D, *f* D, *g* D, *h* D, *i* D, and *b* D, which is equal in length to C D; observing that within those lines the different arch of each rib is to be described, viz., the arch S *a* is a quadrant of a circle, having *t* for its centre, and is equal to the arch of the rib *e* D:—The lines S *u*, S *z*, equal to *z b*, *b u*, are the semi-transverse and conjugate axes of a semi-ellipsis, whose arch S *b*, is equal to the arch of the rib *f* D, which may be struck either with a trammel, or by the intersection of lines. Moreover, the lines S *z*, S *v*, equal to *v c*, *c z*, are the semi-transverse and conjugate axes of a semi-ellipsis, whose arch is equal to the arch of the rib *g* D; and so of the rest.

"Now, having the ribs all ready, set the front rib, A D B perpendicular on the plate A *e* B, as at A B, and fix the feet of the short ribs on the plate A *e* B, as at *e*, *f*, *g*, *h*, *i*, which correspond with the points *n*, *o*, *p*, *q*, *r*, and their points

a, *b*, *c*, *d*, *e*, to the crown of the front rib at D; and thus may you finish your work."

We now proceed to Smith's *Carpenter's Companion*, and though he presents nothing new in geometrical principles, his observations are very judicious and worthy of transcription; and his practical remarks, though perhaps objectionable in a few instances, are more to the purpose of a general connected detail of what should be done in the constructive part of carpentry, and more systematic, than those of most other writers; though the examples and designs which he shows are not generally the best. He begins his introduction thus:

"The usefulness of carpenter's work in building, and the little notice taken of it by authors who have treated of architecture, and the few there be that rightly understand it, prompted me to write the following treatise.

"Carpenter's work is one of the most valuable branches of architecture; it was contemporary with the first ages of the world; and with the knowledge of this art, Noah closely and firmly connected those timbers in the ark, which were so nicely wrought, that they not only kept the water from penetrating into it, but were proof against the tempest and the rolling billows, when, in its womb, it carried all the tenants of the earth and air.

"Those naval preparations, through all ages of the world, as well as those stupendous temples and edifices, erected in all countries, demonstrate the perfection of this art. The innumerable *floating buildings*, which roll from one country to another, through tempestuous storms, tossed from the mountain's height to the depths of the ocean, without injuring the vessel, evidently show the vast use and judgment of carpenter's work.

"But as that branch of it which relates to *templar* or *domal* uses, is the subject of this work, I shall only treat of its usefulness in them; and may venture to affirm that carpenter's work is the chief tie and connection of a building, supplying the ligaments which bind the walls together.

"The bond-timbers, which strengthen and tie the angles of a building, and prevent its separating, is the work of the carpenter. Linteling over doors and windows, with other dischargements of weight, it is his care to perform.

"Bond timbers in cross walls, when settlements happen, if they are well applied, prevent the cracking of the walls, for they keep the whole together, and every part settleth alike, which would fill the buildings with gaps and chasms if neglected.

"Next for the floors; the rightly framing them, by trussing the girders, by placing them on joists, so that they come near no funnels of chimneys; the manner of tenanting, tusking, framing of timbers for chimneys, stairs, &c. I say, all these it is the business of the carpenter to see carefully performed.

"Partitions of timber, their manner of trussing to prevent cracking, settlements, &c., and the discharge of weight of girders, beams, or cross walls, is carpenter's work; as is, likewise, the framing of timber bridges.

"Roofs of various sorts, for common houses, large edifices, or churches, their manner of framing, the height of their pitch, their strength, usefulness, &c., with the various manner of performing all these works, is the subject of this treatise, which I have rendered intelligible to every capacity, by designs of several sorts, and have described them in such a manner, as will render the work useful to carpenters; particularly to those who are unacquainted with the manner of performing these operations of framing.

"The first thing which the carpenter must consider, for the carrying on a building, is the plan, in which you are to prepare your timber, in having it cut into proper scantlings, which shall be hereafter noted.

"You are to prepare for lintelings and bond-timbers; for lintels over doors or windows, stuff of five inches thick and seven broad, and it is a slight way of building to put in any of less scantling; as for door-cases their manner of making, and scantlings of stuff, it is needless to speak of; it is the best way to have them put in when the foundations are brought up high enough for them. Bond-timbers should be dovetailed at the angles of the building and cross walls. And here note, that it is a durable, though expensive way, to have all fir timber, which is laid in the walls of the building, to be pitched with pitch and grease mixed together; the quantity of grease, one pound to four pounds of pitch. All these things are the care of the carpenter.

"Bond-timbers should be four or five inches thick for cross walls, and in the angles of a building, six or seven inches, and proportionably broad; six or eight feet long in each wall; and it would not be amiss to place them six or eight feet distant all the height of the building, in every angle and cross wall; these, if a building be on an infirm foundation, cause the whole to settle together, and prevent the cracks and fractures which happen, if this be neglected.

"We come now to the floors, in which these things are to be observed—the magnitude of the room, the manner of framing, and the scantlings of the timber. For the first, you are to observe to lay the girders always the shortest way, and not to have a joist at any time exceeding twelve feet in length.

"The first common method of framing floors, is where the joists are framed flush with the top of the girder." (*The trimming-joists supposed to come against chimneys and stairs, are always thicker than common joists, being weakened by mortising.*) "The scantling of joists, when a floor is framed in this manner, ought to be as followeth:

Common Joists.		Trimmers.	
ft. long.	Scantling in inches.	ft. long.	Scantling in inches.
5	7 by $2\frac{1}{4}$	5	7 by 3
6	7 by $2\frac{1}{2}$	6	7 by 4
8	7 by $2\frac{3}{4}$	7	7 by 5
9	8 by 3	8	8 by 4
10	8 by $3\frac{1}{4}$	9	8 by 5
11	8 by $3\frac{1}{2}$	10	9 by 6
12	9 by 4		

"These are such proportions as will render the work sufficiently capable of sustaining any common weight.

"The next manner of framing floors is with binding-joists framed flush with the under side of the girder; and about three or four inches below the top of the girder, to receive the bridgings, which are those which lie across the binding-joists, and are pinned down to them with pins of wood, or spikes of iron. These binding-joists should be framed about three feet, or three feet six inches distant from one another, and their thickness four or five inches, or in the proportion to the length of their bearing, as trimming-joists.

"These floors, if they settle out of a level with the building, are made level when the bridgings are put in, which is generally after the building is covered in, and near completed; they are generally double-tenanted. The binding-joists are chased, and the ceiling-joists tenanted into them, and put in generally after the building is up. These ceiling-joists should be 13 or 14 inches apart, and the scantling 2 or 3 inches square, and in large buildings 3 and 4. As for the bridgings, which lie on the top of the binding-joists, they

may be placed 12 or 14 inches distant, their scantling 3 and 4, or $3\frac{1}{2}$ and 5, their bearing being only from binding-joist to joist, which is 3 feet, or 3 feet six inches, and these are laid even with the top of the girder, to receive the boarding. We come now to speak of girders; and first, for their scantling, take these proportions:

ft. long.	Scantling in inches.		
	B.		D.
10	8	by	10
12	$8\frac{1}{2}$	by	10
14	9	by	$10\frac{1}{2}$
16	$9\frac{1}{2}$	by	$10\frac{1}{2}$
18	10	by	11
20	11	by	12
22	$11\frac{1}{2}$	by	13
24	12	by	14

"And observe, that as every weight, added to the weight of the timber in the floor, in itself occasions it to settle, the girders should be cut camber; if a 10 feet bearing, half an inch camber; if 20 feet bearing, an inch camber, &c., in proportion to the length of the bearing.

"And farther to strengthen the girder, and prevent its sagging, as it is called among workmen, that is, its bending downwards, I have given you several ways of trussing girders, which have been most of them practised.

"The manner of trussing these girders, is, first, to saw the girder down the middle, the deepest way; then take two pieces of dry oak, about $4\frac{1}{2}$ or five inches wide, and 4 inches thick; let half the piece be let into one side of the girder and half into the other.

"Another way, which is by cutting the girder through, and driving a wedge against the ends of the trusses. When these are thus prepared, bolt them together with iron bolts and keys; or much rather, a screw at the end of the bolt.

"Some carpenters cut their girders down the middle, and bolt them together, without trussing, only changing the ends different from what they grew, whereby the grain of the wood is crossed, and it becomes much stronger than if it had continued without sawing down the middle, and thus putting it together.

"Some, in trussing girders, make use of other trusses.

"The girder being thus trussed and put together, proceed in framing the joists, as in common floors. The strongest way being double-tenanting and tusking, as is shown in the binding-joists. Before I leave this part of floors, I shall observe to you, that the best and most workmanlike manner of framing floors, is to plane the upper edge of your joists straight; for the straighter and truer your joists lie, the truer your boarding will lie, which is a great ornament to a magnificent room; but if you frame without binding-joists, and lay on bridgings, plane the bridgings and lay them very straight and level; this care taken will save a great deal of trouble in laying down the boarding, which you are often forced to chip and fur up, to make them lie even, and those furrings are not only troublesome, but are apt to give way, and occasion the creaking of the boards as you walk on them. It would be a good way to turn arches of brick over the ends of the girders of the floors, because if any alteration happens, they are easily taken out.

"I come now to partitions of timber, with their manner of framing. Timber partitions have these properties attending them: they take up less room, and are cheaper than those of brick.

"As to roofs, there is a plate to go round a building, which may or may not be deemed a part of the roof; it may be deemed the foundation and tie of the roof and walls; or it may be taken as only that on which the roof lieth. These plates are to be dovetailed at the angles, and tenanted together in their length, several ways. The beams of the roof, which serve as girders to the ceiling-floors, (and into which all the principal rafters of the roof are tenanted,) are dovetailed, or what by workmen is termed *cogged* down, to the plate, which prevents its flying out from the foot of the rafter, whose butment is against it; and in the angles of a building, pieces dovetailed across the angles of the plate, serve to keep it from spreading, and is the foot of the hip.

"The common pitch of roofs is to have the rafter's length, if it span the building at once, to be three-fourths of the breadth of the building. Some make them flatter, as a pediment pitch; and the old Gothic way was to make them the whole breadth.

"The common pitch is not only unpleasing to the eye, but is attended with this inconvenience; if there is a gutter round the building, the steepness of the roof occasions the rain to come with so sudden a velocity into the pipes which are to convey the waters from the gutters, that they fill the gutter; and sometimes so fast, that the water runneth over the covering of the roof, and does great injury to the timber, &c., of the building: and the steeper the roof is, the longer the rafters, and the greater quantity of timber must be used in the roof, as well as the more weight from the great quantity of timber and the weakening the principal timbers, by adding more to its own weight.

"And the pediment pitch is inconvenient, in lying too flat, for those climates so frequently subject to rain, and heavy snows, which last would press and vastly incommode the building, and would lie much longer on the roof, its declivity being so small; besides, in keen winds, attended with rain, the rain would drive in under the covering of slate or tiles, and create much decay in the timber.

"Proportion of beams whose bearing varieth; take the following rule:

Length of Beam in feet.	Scantling in inches.		
12	6	by	8
16	$6\frac{1}{4}$	by	$8\frac{1}{2}$
20	$6\frac{1}{2}$	by	9
24	7	by	$9\frac{1}{2}$
28	$7\frac{1}{2}$	by	$9\frac{1}{2}$
32	8	by	10
36	$8\frac{1}{4}$	by	$10\frac{1}{2}$
40	$8\frac{1}{2}$	by	11
44	9	by	12

"The principal rafter should be nearly as thick at the bottom as the beam, and diminish in its length one-fifth or one-sixth of its breadth; the king-posts should be as thick as the top of the principal rafter, and the breadth according to the bigness of the struts you intend to let into them, the middle part being left something broader than the thickness.

"Struts may diminish, as the rafters do, one-fifth or one-sixth of their length. In placing struts and collar-beams, the dividing the rafter into as many equal parts as you propose bearings, is the rule, because every part of the principal will have its equal distant bearings.

"Purlins are of the same thickness as the principal rafter, and the proportion of the breadth is six to eight; that is, if the rafter be six inches thick, let the purlins be six inches thick, and eight inches broad; if it be nine inches thick, the breadth of the purlins is twelve inches broad, &c.

"N.B. The purlins are those pieces into which the small rafters are tenanted, and they are tenanted into the principal rafter. Length of purlins is generally from six to eleven feet, not exceeding that length.

"Small rafters: their scantlings two inches and a half, and four inches; three inches, and four inches and a half; and three inches and a half, and five inches; according to the magnitude of the roof and length of the rafters. Small rafters should not exceed seven feet in length in a purlined roof; if it happen that the length of the principal be above fifteen feet, it is best to put in two tier of purlins in the length of the rafter."

In respect to the construction of roofs for coves, he has the following observations: "The use of coving a room of considerable height, is, first, the making of it much lighter than it would otherwise be, if level in the ceiling; the rays of light in a cove are reflected back again into the room, which would be otherwise lost and confused in a roof with a flat ceiling.

"Likewise, all rooms with circular roofs or ceilings are more commodious and useful for entertainment, for music, &c. The angles of incidence are always equal to those of reflcetion; so the undulation of sounds flying on any cove or spherical part of a building, reverberate on the audience; and if spherical, no part of the sphere can receive the vibration, but it will return in the same direction from whence the undulation first began. The reflecting rays of light, and the reverberation of sounds, proceed from the same cause, and from incidents naturally affecting the eye and the ear."

It may be proper here to state, that though the reflection of sound is analagous to that of the rays of light, the laws and modifications by which sound is propagated to the ear, are less perfectly understood: it may, however, be observed, that in vaulted apartments, it is necessary to reduce the pitch of the voice, and to speak slowly and distinctly. The best writers recommend the ceilings of theatres to be arched, as has been practised in some of the most distinguished edifices of this kind in Europe.

This author likewise gives the method of finding the length of hips, both with and without a plan, as shown by Godfrey Richards, at the end of his *Translation of the First Book of Palladio.*

The work of Mr. Smith contains, in all, thirty-three plates of carpentry, arranged in the same order as he has treated the subject. Of these, twenty are plates of roofs, some of which are tolerably good examples, and at the end are five plates of timber bridges. His methods of joining-work are shown in the following descriptions and their corresponding diagrams.

Plate IV. shows his method of cocking beams down upon the wall-plates; Figure 1, by two dovetails, and Figure 2, by three dovetails. Dovetailing is a very bad method at the best; for, when the taper is small, the shrinking of the timber allows the beam to be drawn out of the socket in proportion to the quantity to which it is reduced in its breadth. The fewer the number of dovetails in the breadth, the weaker will the end of the beam be, or otherwise they must hvae less taper; and if the number of dovetails are increased, the parts of them formed on the end of the beam will be apt to split off. But, in modern Carpentry, the beam can never be drawn from the wall-plate, as the abutting parts are in a plane perpendicular to the length of the beams.

Figure 3, shows his method of framing wall-plates at the angles, with the diagonal and dragon pieces, where all the timbers appear to be let in flush with each other. This mode is much inferior to the present practice, where both the angle-tie and dragon-piece are fixed above the plates, which position not only allows a much firmer hold one to another, but also a much better support for the hip-rafter to stand upon.

Figure 4, represents four different methods, shown by him, for naked flooring. "The first method of framing is that marked A, where the joists are framed flush with the top of the girder; the two cross joists, marked *a* and *b*, are called *trimming-joists;* that marked *a* is supposed to come against a chimney; that marked *b* is the stairs." Here he shows that the joists *a* and *b*, should be thicker than the common joists, because of the mortising; but with equal reason he should have allowed the joists *c, d, e,* into which the joists *a* and *b* are framed, to have also been stronger; for one mortise in the middle of a beam will weaken the beam as much as if it had been cut full of mortises. He gives no name to the joists *c, d, e,* which should have been named, in order to transfer the idea from one to another, without circumlocution, or having recourse to description. His next manner of framing floors is that shown at B. "The six joists marked *b* are the binding-joists framed flush with the under side of the girder, and about three or four inches below the top of the girder, to receive the bridgings, which are those marked *m* in the floor, and which lie across the binding-joists," at C. In the other compartment, D, are shown the ceiling-joists, *n*, the bridgings being supposed to be removed for the purpose of showing them.

Figures 5, 6, 7, 8, he says, show the manner of tenoning the binding-joists, the tenons being generally made double.

Figures 9, 10, 11, 12, he observes, are common tenoning, which seems to imply a less sufficient method than the former. These last four examples, with the single tenons on the end of each, are much to be preferred to the double ones on the ends of Figures 5, 6, 7, 8, which are not only difficult to execute, but are calculated to weaken the mortised piece, which is to receive them, by the slanting shoulders of the tenons; his observation is the very reverse of what is now asserted, as he observes, in page 17 of his work, "the strongest way being double tenanting and tusking, as is shown in the binding-joists."

Figures 13, 14, 15, and 16, are exhibited in the third plate of his work, but he does not describe them; we suppose them to show the method of lengthening beams. The two methods, Figures 15 and 16, are extravagant ideas, being not only difficult to execute, but weak as a tie, and incapable of making a sufficient resistance to a longitudinal strain.

Figures 17, 18, 19, 20, 21, 22, 23, 24, 25, are various methods which he shows for trussing girders. He observes, that the trussing pieces or cores are let half into each flitch, and the scantlings of these pieces to be about $4\frac{1}{2}$ or 5 inches wide, and 4 inches thick. Figure 18, he says, "is another way, which is by cutting the girder through, and driving a wedge against the ends of the trusses, as the wedge *d;* when these are thus prepared, bolt them together with iron bolts and keys, or, much rather, a screw at the end of the bolt." This method, though not the best, is certainly a tolerable approximation to what may be called good. He does not mention how the pieces *a, a,* are to be tightened in Figure 17. He observes, that "some in trussing girders, make use of other trusses," as in Figures 20 and 21. These hardly deserve comment, being the weakest forms that can be conceived. The trussed girders, represented by Figures 24 and 25, he claims as his invention, with one inverted arch, which he proposes to be of iron. Nothing could be more unmeaning than these examples.

The observation which he makes in respect to Figure 24, is void of principle, and contrary to mechanical strength;

his words are, "The upper arched one I take to be of great strength, though the trusses are inverted; for the pressure being upon an arch whose butment is good, I think a great weight can no way occasion the bending of the girder."

We come now to the *British Carpenter*. Though Mr. Price's order of treating his work is not so regular as the method adopted by Smith, his descriptions and observations are very correct; and, with the exception of a few references, there is hardly anything wrong.

This author begins with the scarfing of beams, as represented in *Plate* V. of our Work, Figures 1, 2, 3, 4, 5, 6. He says that the methods shown by the diagrams 3, 4, 5, 6, are the strongest; perhaps in consequence of their being tabled into one another; and that represented by Figure 6, has this property, that the pieces may be put together without any waste at the ends; he observes, that it is not his intention to limit the lengths of these scarfings, but only to show the manner of tabling the pieces together: he might also have said, that though nothing determinate with regard to the lengths of scarfings could be done, the greater the extent of the joint in the direction of the fibres of the beam, the more will it be disposed to resist separation, though there will be a greater waste of timber. Those represented by Price are much superior to those in Smith's work.

He then describes the method of trussing girders of greater extent than 24 feet, as we have shown in Figures 7 and 8; and proposes that the pieces which are to constitute the core be made of good dry straight-grained English oak, 4 inches by 3, or 6 by 4, as the strength may require, and let half into each piece; the pieces of the core being inserted in the one half, so as to abut firmly at the ends, and the two flitches put together so that the internal braces may abut firmly at the ends of the other flitch, and then bolted together, will complete the girder; he prefers that of Figure 8, to Figure 7, as being divided into three parts, it raises the pitch of the braces, and though the middle part is left untrussed, it may be looked upon as an inflexible solid, as the proportion of the breadth to the length is reduced much nearer to a ratio of equality than the dimensions of the whole beam, the depth being the same in both cases. The flitches, he observes, may be mortised through at the lower end of each truss, and the core tightened by wedges driven therein. Girders constructed in the manner of these two examples are much better calculated to perform their office, than those before given by Smith, which are void of every principle of mechanical science.

This author then speaks of the method taught by Alberti, as follows:—"Take two pieces or flitches, being well dried, and turn the but end of the one to the top end of the other, without trussing at all, and bolt or screw them together."

Mr. Price then proceeds to the various joints in roofing, as in Figure 9, which represents the junctions of the struts and principals with a king-post.

Figure 10, is another mode, which he uses where the breadth of the bottom of the truss-post will not allow a right-angled abutment to the direction of the strut: he makes the angle on the end of the tenon, with good reason, equal to the angle made by the shoulder, but on the contrary side, so that the two abutments may contract each other's efforts in moving the strut up or down on the side of the said post.

Figure 11, represents his method of forming the end of the tie-beam and lower end of the principal, so as to form a joint with double mortise and tenon, which, he says, presents greater resistance than when made with single mortise and tenon.

Figure 12.—No. 1 and 2, show the proportion which the mortise or tenon ought to have to the breadth of the stuff, either for the joints of roofs or truss partitions, by making the tenon or the mortise one-fourth of the breadth of the whole, and keeping the mortise and tenon in the middle.

Figure 13. No. 1 and 2, another mode for the same purpose, not much in request at the present time.

Figure 14. No. 1 and 2, the manner of joining the binding-joists and girders in floors, the same as used in the present time, with a tusk or sloping shoulder, and the double resistance or butment.

Figure 15. "No. 1 is called a *bridging-floor*, as being framed with a binding or strong joist in every three or four feet distance, and flush to the bottom of the girder, so that when the house is covered in, you pin down your bridgings thereon, and flush with the top of your girder; and this is the best way of carcase-flooring." The section of this floor taken transversely across the binding-joists is shown at No. 2, Figure 15. Mr. Price observes, that the best way to lay girders, "is not to lay them over doors or windows, nor too near chimneys; and, at the same time, to have the boards lie all one way;" and hence the oblique position of the girder, as here represented, is occasioned by the fireplace.

Figure 16. No. 1, a carcase-floor with single joists, or without bridging-joists. These are framed flush with the top of the girder, "and have every third or fourth joist the depth of the girder, and those between more shallow." No. 2 shows the ends of the joists, and the ceiling-joists framed into the deep joists. No. 3, the sides of the deep joists, with the pulley-mortises, in order to receive the ceiling-joists.

Mr. Price then proceeds to lay down the sides of roofs in plano, and shows the backings of the hips in the same manner as has been detailed by Godfrey Richards in the former part of this article, according to Pope's principle.

We shall here transcribe one of his examples, in which he attempts to show, for the first time, a method for finding the joints of purlins upon hip-rafters: his process, which is as follows, is tedious; his diagram and explanation are both obscure and defective, but show some novelty of form and geometrical skill in lines.

"Admit the plan (Plate VI., Figure 1, No. 1) was required to be enclosed with a hipped roof: first, find the middle of it, as *f*; then draw the bases of your several hips, as *a f*, *b f*, *c f*, *d f*, and *e f*; resolve on some pitch or height, as in No. 2, at *f g*; to this section bring all the bases of your respective hips, as the letters of reference show; this gives you the length of each respective hip; therefore, from the section No. 2, you describe the skirts round the plan No. 1, as *a b g*, *b c g*, *c d g*, *d e g*, and *e a g*, which form the roof required.

"To find the back of any hip, do thus: Draw a line at pleasure, crossing the base of the hips at right angles, as the line *h i*, which crosses the base of the hip *c f*; observe where it passes through the sides of the plan; on the base line of this hip, raise its section from No. 1, as *c g f*; lastly, place one foot of your compasses in the intersection, as at *y*; open the other foot, till it touch the hip *c g* at its nearest distance; draw a small section till it cross the base, as at *k*; so is *h k k i* the back of that hip; *and is the most exact, and easiest method that ever was delivered for this purpose;* the shadowed part, O, is the section of the supposed timber the hip is shaped out of, being cut off at right angles with its side and back. What is said of this explains the hip *a f*, whose back is *l m n*, and its section P is shaped so as to have the purlin come square against it; the letters of reference show the rest."

"*To find the side joint of a purlin* (*in case the hip be not shaped as above*) *so as to cut it by a templet, supposing there be no room, or occasion to frame it into the hip.*—For example, take any two hips from the plan No. 1, as *e f* and

$a\ f$, which to keep from confusion is transferred as to No. 3, and admit the plan of the purlin to be $o\ p$; first, raise the sections of the hips from No. 2, as $e\ f\ g$ and $a\ f\ g$, as the letters show; then raise perpendiculars at o and p to the back of the hips, as $o\ q$ and $p\ r$; lastly, draw a line from the point q, and at right angles from the back of the hip $e\ g$ (as it is so near to a square, or else it should be drawn from the back of a rafter standing at right angles with the sides of the plan) observe where it cuts the base line, as at s; draw the line $s\ t$ parallel to the purlin: lastly, draw the line $t\ r$. From all which you take the templet Q in T (see No. 4) in the following manner: Draw the line $u\ w$ in No. 3 at right angles from the side $a\ e$, which transfer to No. 4, as $u\ w$; take from No. 3 the distances $u\ s$ and $u\ t$, and transfer them to No. 4; take also the distances $x\ o$ and $x\ p$ in No. 3, and transfer them to No. 4; take also the distances $s\ q$ in No. 3, and transfer to No. 4, as $s\ o$; lastly, take from No. 3 the distances $t\ r$, and transfer to No. 4, as $t\ p$; so that Q is the templet to cut the side, and the skirt $e\ a\ g$ is the templet to cut the back. I think any farther explanation needless, because by a little serious inspection, the reader may see that all the lines necessary to be understood in a roof, are contained in this Plate.

"That is, all the parts of a roof may be cut by templets, as these lines, and the explanations of them, do direct; and although I have shown but one example for the cutting of any purlin that comes against a hip, as explained in $h\ k\ i$, (Figure 1, No. 1) I hope it will be sufficient, because the method in l, m, n, cuts off all such difficulties, and is equally strong."

In this description, he is unintelligible, vague, and erroneous: there is a certain tendency towards the principle, but he loses sight of it. He is negligent in directing his reader to raise perpendiculars at o and p, the bases of the two hip-rafters, instead of raising a section at right angles to the base and to the wall-plate $a\ e$. He tells us to "draw the line $u\ w$ in S (which is here No. 3) at right angles from the side $a\ e$, which transfer to T (or No. 4) as $u\ w$;" but he makes no use of this line, which is the line on which the width of the templet should have been extended. Then he says: "Take from S (No. 3) the distances $u\ s$ and $u\ t$, and transfer them to T (No. 4); take also the distances $x\ o$ and $x\ p$ in S (No. 3), and transfer them to T (No. 4);" but he does not show how the distance between the lines $p\ o$ and $t\ s$ are obtained in T (No. 4); and thus, after a long and tedious description, he leaves the construction vague, and obtains nothing but uncertainty. We shall here complete what he has unsuccessfully attempted.

Let the same plan $a\ f\ e$ be laid down at No. 5, as at No. 3; draw $f\ w$ perpendicular, and $f\ g$ parallel to $a\ e$; make $f\ g$ equal to the height of the roof, and join $g\ w$; let $p\ o$ be the place of the purlin, parallel to $a\ e$, meeting the bases of the hips at o and p; produce $p\ o$ to meet $w\ g$ at q; draw $q\ u$ perpendicular to $w\ g$, meeting $f\ w$ at u; parallel to $a\ e$, draw $t\ u\ s$, meeting the bases $f\ a$ and $f\ e$ of the hips at t and s.

In No. 6, draw U X, which make equal to $u\ q$, No. 5; draw T U S and P X O perpendicular to U X; make U S, U T, X O, X P, respectively to $u\ s$, $u\ t$, $x\ o$, $x\ p$, and join T P and S O; then P O S T is the templet required, or any parallel portion of its breadth.

The reader will observe that this is found by much fewer lines; and there is no occasion for raising the sections of the hips, but only the section of the rafter at right angles to the wall-plate.

No. 7 is another invention of the author of this Dictionary, founded upon the same principle as No. 5 and 6; but the construction is confined to one diagram, thus: Let A B C be the seat of the part of the roof; describe the section C $d\ e$ as before: draw C f perpendicular to $d\ e$, cutting $d\ e$ in f; from C d cut of C g equal to C f; parallel to A B draw $k\ f$, cutting A C and B C in k and l; likewise draw $h\ i$ parallel to A B; perpendicular to $k\ l$ draw $k\ m$ and $l\ n$, cutting $h\ i$ at m and n; and join C m and C n; then will the angles at m and n of the triangle C $m\ n$ be those required for forming the end of the purlin, in order to form a junction with the hip-rafter.

We now return to Mr. Price, who, in laying down the framing of roofs in plano, or in ledgement, begins thus: "Every man who frames roofs, does first piece his plates, cock or dovetail down his beams on the said plates, and prepare pieces on which his hips are to stand; as appears in this plan Q, at Y and Z." (See *Figure* 2.)

"Then he frames his principals, as R, and likewise his hips, as S, into pieces prepared for them to stand on; and although all these respectively are framed for the generality on the floor, and when in practice is the best way, they are here placed by themselves to avoid confusion.

"I hope the pricked lines are enough to show that the *skirts* T, V, W, X, are laid out agreeably to the plan Q; and in which are shown that one purlin lies above the strut, and the other below it; for if they were all to lie in a right line, in the first place it cuts the stuff to pieces, so as to weaken it still more, and at the same time you lose your pinning.

"Here is shown a method to turn up your hips without backing at all; and is thus: your hips being first framed into the pieces they are to stand on, take a broad board, or small panel, lay it on the place where your respective hip stands, and there mortise it as if it was your beam; cut off the corners of it, so as to make its angles agreeable to your plan, whether square or bevel; lastly, when you come to turn up your hip in framing the skirts, slip this mould, as Y, upon the tenon at the foot of your hip, and then give it a tack with a nail, and the angles of that board will turn up a hip as desired, and is far preferable to any other method whatever.

"But because sometimes buildings must be level, and necessity requires the beams to be laid so, to miss some chimney or window; therefore let A (*Figure* 3) represent a bevel plan, whose beams also lie bevel at the time of framing; and that is just as much as half the beam that the rafter stands on; the skirts B, C, D, E, are the same way shown as before.

"I hope it will not be taken ill, my saying that a man must be deprived of sense, who would run into almost endless trouble of cutting his timbers all bevel, unless some unavoidable necessity require it, but rather use the method I propose in plate E." (That is, *Figure* 2 of this article.)

The method of laying roofs in plano is first shown by Price. It seems to have been much practised in his time, and indeed till lately; but to perform the work in this way, requires the most ample space, and the utmost care of the carpenter in placing his timbers; without this it will be difficult to bring the work together with exactness. In the present practice, the timbers may be all cut to their lengths and angles before they are applied to their places, and then they may be fitted together on the ground before they are raised on the building.

In roofing, his rules for finding the pitch of the rafters for different coverings, are these (page 15 of his work): "A leaden covering requires the height two-eighths or one-fourth of the breadth of the beam; a pantile covering, three-eighths; and plain tiles, four-eighths or one-half, which brings the vertical angle of the roof to a square."

But in the following plate, H, of his work, he is not very consistent; he delivers different rules, which are to the

following purpose: divide the breadth into six equal parts for pantiles, into seven for slates, and into eight for plain tiles; then in each of these the whole number, wanting two, will be the height of the roof; that is, pantile $\frac{4}{6}$, slates $\frac{5}{7}$, and plain tiles $\frac{6}{8}$, of the breadth of the beam."

The following observations, with respect to the trusses of roofs, are very judicious:

" That the less in number the divisions or pieces are, that compose each truss, the stronger it is; for even the shrinking of the wood will let a well-framed truss sag or drop in process of time; for which reason I cannot help recommending English oak, particularly for king-posts." He recommends square bolts in preference to round ones; " for this reason: if you use a round bolt, it must follow the auger, and cannot be helped; by this helping the auger-hole, that is, taking off the corners of the wood, you may draw a strap exceedingly close, and at the same time it embraces the grain of the wood in a much firmer manner than a round one can possibly do." With respect to strapping, he observes: " If it be objected that there is too much trust reposed on the iron-work, may it not be asked, if any common strap at the bottom of a king-post was ever known to break by continual pressure? Witness the straps in a theatre, to which is fixed a prodigious weight." With respect to timbers, he says, " If purlins are used, they ought to be agreeable in number to their supports;" " but if bridged, need not be regarded."

The following designs, which he shows for the fronts of buildings, which are required to have the ground story open, and supported with story-posts, may be useful to some:

" In *Figure* 4, is shown the manner of a timber front, supposed to be open underneath, in form of an arcade. And for such open fronts, the foundation should be laid on reversed arches, which will strengthen it very much; by this means, the ground bears between one post or pillar and the other, as well as under the same.

" If on it you would have brickwork, or even stone, then support the bressummer, as is shown in *Figure* 5, which manner of framing renders it as strong between the posts or pillars as it is directly on the same, and this seems sufficient to explain proper bearings for partitions."

Mr. Price then proceeds to circular domes, and in their construction shows, for the first time, how the purlins are to be squared; his description is as follows:

" Of what has hitherto been described, nothing appears so beautiful when done, as domes or circular roofs; and, as far as I can perceive, nothing has appeared so difficult in doing, therefore it will be proper to speak something of them."

Plate VII. Figure 1.—" Let B represent a plan, in which let *b*, *b*, *b*, be the plate on the supposed wall; and let *c*, *c*, *c*, be the kirb on which stands a lantern, or cupola; also let *a*, *a*, *a*, represent the principal ribs.

" From the plan B make the section A; in which the kirb or plate *b* should be in two thicknesses; as also that of *c;* by which it is made stronger; and indeed the principal ribs would be much better to be in two thicknesses. The best timber for this use is English oak; because abundance of that naturally grows crooked. As to the curve or sweep of this dome A, it is a semicircle; although in that point, every one may use his pleasure; and in it are described the purlins *d*, *e*, from which perpendiculars are dropped to the plan B; so that *f* is the mould the lower purlins are to be cut out by, before they are shaped or squared for use; and that of *g* is the mould for the upper purlins. I rather show it with purlins, because under this head may be shown the manner of framing circular roofs in form of a cone.

" To shape these purlins, observe, in A, as at *d* and *e*, they are so squared, that the joints of the supposed small ribs are equal. Observe, as at *e*, the corners of the purlin, from which the perpendiculars are let fall to the plan B. So that your purlin being first cut out to the thickness required, as appears in *e*, and also to the sweep *f;* so that *k* is the mould for the bottom, and *l* the mould for the top; by which, and the lines for the corners of the said purlin *e*, the same may be truly shaped and squared.

" N.B. This particular ought to be well digested, it being a principal observation in a circular roof.

" From the purlin *d*, in the section A, perpendiculars are dropped to the plan B; in which it appears that *h* is the mould for the top, and *i* the mould for the bottom; so may this be squared, which completes the performance. As to other particulars, due inspection will explain them. If any should say, a dome cannot be done so safe without a cavity as usual, let them view St. Stephen's, Walbrook, Stock's-market, built by that great architect, Sir Christopher Wren."

He then shows the method of covering polygonal buildings:

Plate VII. Figure 2. " Let A be the plan, the upper part of which is half an octagon. It is observable that a circular roof, as B, should extend no farther than the upright of its support, and there made so as to carry off the water; whereas an ogee roof, as C, may extend to the extremity of the cornice, without injury to its strength, or offence to the eye of the most curious: also, a hollow roof, as D, may extend to the extremity of the cornice.

" It appears to me, that many angles of a cupola give it beauty; therefore the sweep E (*Figure* 2) is a regular curve, the base line *l k* being taken from the angle of the octagon in the plan A, as at *l k*. This curve, E, is divided into a number of equal parts, in order to trace the common rib, F, from the said angular rib, E: observe, in A, the base of the common rib, *f l*, which is placed in F, as from *l* to *f;* continue the perpendicular, *l*, at pleasure; take the base *l k* in E, on which are the perpendiculars dropped from the curve, and observe to place that distance, *k l* in E, from *f* in F, to any part where it cuts the perpendicular *l* in F, as at *m;* from these divisions raise perpendiculars, so by continuing the base lines from the divisions in E, to these perpendiculars in F, their intersection or meeting is a curve, or sweep, exactly agreeable, and which, indeed, may serve as a standard rule to trace any moulding whatever.

" To back the said angle-bracket, D, observe to describe the thickness of it on your plan, as in A at *k*, which shows how much your mould must be shifted, as may appear in D. This also may be observed to be a general rule for the backing of any bracket."

These methods are certainly founded on truth, but his diagrams are not laid down in the most obvious way; being so scattered as not only to be tiresome to the eye, but to occasion also a long and tedious description. He then proceeds with the centerings of groins, as follows:

Figure 3. " Let A be the plan of a vault to be centered for groins. At *a*, *b*, *c*, *d*, are piers, generally prepared in with the foundation, which bear the weight of the brickwork. First, resolve on the curve you would have, as *d e c*, being a semi-circle, which is shown by the section B. Begin in A at *d e c;* centre through as it were a common vault, and board it; which being done, to make your groin set centres, as from *a* to *c*, and from *b* to *d*, divide the curve *d e c* into four equal parts, as at *g* and *f;* so are *g e f* small centres, you will want to nail on the centres first boarded, whose place or plan is at *h;* these small centres may be put in at pleasure, according to the bearing of your boards, that is, as to the distance between each centre. To make your groin straight on its base, at some little height over the centres, strain a line from *b* to *c*,

or from d to a, from which drop perpendiculars on your boarding, first fixed at as many places as you please; there drive in nails, and bend a straight rod till it touch them all; and then, with a pencil or chalk, describe the curve so formed, to which bring the boards to be nailed on these little centres, and their joints will form a straight groin."

Figure 4. "Let C be a plan of greater extent, and which suppose to be supported by two piers, as *f*, *l*. The section D is composed of entire semicircles, then consequently your curves in the section E will be elliptical, as *b n d*, and may be described with a trammel. What was said in A explains this at one view.

"If these pillars should be in the way, view the plan and sections again: first, form the principal curve, as D at *a g h b*, being an ellipsis, so that the centres will be a Gothic sweep against the windows, as *e g a*: trace the curve *d h b* in E, agreeable to *e g a* in D, with which centre it, as shown in A, and make good your groins to the sides: lastly, make a flat centre, as at *g h i k*, which flatness is shown in either of the profiles or sections D and E, and fix it on your centres before completed, which doubtless due inspection will make plain, and hereby you avoid the pillars, which are equally firm.

"N.B. The cause of these centres against the windows being a Gothic arch, proceeds from their making part of the whole sweep or arch, which though it does not add to its beauty, it does to its strength in a particular manner."

After showing how to find the groined lines, as it were by a mere mechanical process, the method of finding the groined lines on the body centre, he then shows how the same may be found upon true geometrical principles, which may be looked upon as the foundation of all kinds of cylindrical soffits.

"Regarding variety, I have given here another method for vaults, and which, indeed, may give more pleasure to the reader, as being a curiosity never before published, and may appear more intelligible than that in the foregoing."

Figure 5. "View the plan G and its section H, which is composed of entire semicircles, as *b f e*: see also the section I, which is an ellipsis traced from *b f e* in H; but for use, nothing is more true than the trammel.

"See this plan again, and also its section I, from which is described the curvilinear face K, and also the face of the semicircular arches, as L, all being alike. And this is what I call a more accurate method for finding the groin, so as to be straight over its base, and at the same time gives a standard rule whereby to account for any curve, or face of a ceiling whatever. The curve in I is divided regularly, though seemingly into unequal parts, which being drawn to the groin in the plan G, as appears by the figures 1, 2, 3, 4, 5, 6, 7, 8, 9, and which are transferred into L at 1, 2, 3, &c. Also the circle *b f e* in H is divided into eighteen equal parts; the half consequently into nine, which appears from *b* to *e* in L. This method doubtless will be plain, and therefore needs no farther explanation.

"That of K belongs to the section I, extended as it were, and that of L belongs to one of the small arches of H, also stretched out, they being all alike."

Here it must be observed, that he has stretched out the piers, which are of no use, the covering only being wanted, and he has extended all the compartments of the plan in plano at K, which is absurd, one of each being all that is necessary; for they cannot be extended in contiguity, nor any two contiguous parts on the plan, though each adjoining part may be done separately.

"N.B. To find the groin by a more common method, do thus: Erect a straight piece of a board, or the like, on the corner of the pier the groin springs from, and drive in a nail at the point of the groin's meeting, on which fasten one end of a chalked line, straining it tight, slide it down the side of the said straight piece, and it will form the groin so as to stand perpendicularly over its base."

Mr. Price then proceeds to the methods of covering the parts of coved ceilings adjoining the angles, and also the coverings of domes, as follows:

Plate VIII. Figure 1. "*Suppose* M *to be the plan of a ceiling, as a b c d, and it is required to have a large frame, gulochi, or panel.*—First, produce some side or end of the room, as N. Let it be required to describe the curvilinear face of the cove. The extent of the end of the said room is *a b f e*, and it is coved one-fourth part of the height, at *m b*. The said frame or panel being *g h*; the quarter circle *m g* is divided into eight equal parts, which are transferred to P, so that *m g h l* is the face of O, as stretched or extended out, on which any thing proposed to be described therein may be truly performed.

Figure 2. "In Q is shown the plan of a niche, or dome; if a niche, let it be demanded to be fineered with walnut-tree, &c. If a dome, let it be required to be covered with boards or lead. Divide it into any number of parts, as here into nine, which transfer to S, as appears from *h* to *l*. Describe the section also, as R, being a quarter of a circle, which divide into any number of parts, as here into five, as is shown in the figure from *h* to *i*, which transfer in the plan Q from *a* to *f*; middle some one division, as from 4 to 5; then take those distances from R, and transfer them to S, as from *f* to 5, so that each division is halved or middled, as *f a*, *f a*: on these lines place the distances from Q, as at *e*, *d*, *c*, *b*, to 1, 2, 3, 4, in S, and these will form such curves as shall meet.

"N.B. The more parts it is divided into, the better and truer it will be performed."

In this description, he is far from being clear, as we shall here explain. "*Take the distances from* R, *and transfer them to* S, *as from f to* 5." But the extent of the line from *f* to *a* at S does not contain the whole stretch of the arch *h i* of the section R, as it contains only four of the equal parts, whereas there are five; one part should have been described to be below the line *f f f*, &c., as the diagram S shows. The words "*so that each division is halved, as, f a, f a*," &c., have no meaning. "*On these lines place the distances from* Q, *as at e, d, c, b, to* 1, 2, 3, 4, in S, *and these will form such curves as shall meet:*" this is extremely obscure, and ought to have been thus described: From the points *b c*, *d e*, in Q, describe the several arcs meeting each of the radii *a f* and *a* 4; then at S, through the divisions, 1, 2, 3, 4, draw lines at right angles; upon these lines, and on each side of the said points, 1, 2, 3, 4, set off the several arcs at Q, beginning with *f* 4, at the bottom of S, and through the points on each side of the line *f a* describe the two curves, and the space comprehended between them and the bottom line is the board required.

It must be observed, that though it is sometimes convenient to detach the parts of a diagram when it would occupy too much space, it is by no means so obvious as one connected figure. In this respect, Mr. Price is very obscure, in transferring to so many different figures.

He then shows the nature of oblique or rampant arches, the tracing of, and the manner of finding the base or seat of the angle ribs of an annular groin, as follows:

Figure 3. "That of A, is supposed to be the mitre-bracket of a cove, whose projection is *b c*; and the height thereof is *a b*; the curve being a segment, or part of a circle, let it be demanded to trace a curve from it, as B, which shall be agreeable thereto, if applied as a common bracket, *e d* being its height, as before, and *e f* its projection; first, divide the

given curve A, into a number of parts, or take points thereon promiscuously, which will answer as well. From these divisions, or points, drop perpendiculars to some straight line, as that of *a c*, observing their meeting with the said line *a c;* and in practice take off all these distances on a lath, or rod, applying the proper end thereof to the projection of the common bracket B, as *f*, observing where the other end passes through the perpendicular line *e d*, as at *g;* there raise indefinite perpendiculars from the said points, then draw the line *d f*. Lastly, transfer the distances, as from the straight line *a c*, in A, to the figures, to that of *d f* in B; which, no doubt, inspection will explain, more especially if the letters and figures be duly observed.

"Now view the same figure A again; and admit it were the curve of a common bracket, let it be demanded to trace a mitre or angle bracket from it, as C; *g h* being its height as before, and *h i* its projection (the method of finding which in either case, no doubt, will be well known to every one:) take the line, as *a c* in A, which in practice (as was before observed) I suppose to be on a rod, or lath, with its divisions, or points on it, and transfer it to C, as *g k;* then draw the line *g i;* lastly, from the said points on the line *g k*, draw base lines, observing their meeting the line *g i;* at which respective places raise perpendiculars, and transfer your several heights from A, as before, observing to place each in its due position. And although the abundance of points should render this method somewhat confused, it may be evaded by making but few points, and driving nails therein, round which a straight lath being bent till it touch them all, the curve may be described with a pencil, &c.

"N.B. This may serve as a general rule for all such curves as are not regular, or cannot be formed with a trammel, supposing either to be the given curve. The principal curve being formed on any plain superficies, it may be taken off on a lath, as before was observed; and by it the required curve may be described on a piece of slit deal, &c., of a width equal to the deflection of the arch from a straight line, with an allowance of wood capable of holding it together.

Figure 4. "That of D, represents a common bracket for a plastered cornice, whose shape the plasterer ought always to be consulted for: let it be required to trace a corner, or angle-bracket from it, as E; first, draw base lines from the respective angles *a*, *b*, *c*, *d*, to the line *t r*, as 1, 2, 3, 4; also perpendiculars to the line *r s*, as 5, 6, 7, 8; and (because an example for finding the projecture of the angle or mitre bracket, may be required) observe to make *r u* equal to *r s;* so is *u s* the projecture of the said angle or mitre bracket; and the points will be *w*, *x*, *y*, *z;* so that by transferring this said line with its points as before to E, as also those of the height as before, draw perpendicular and base lines, when, as no doubt inspection shows, their meeting gives the shape of the bracket as desired, and this also may serve as a standard rule in any such case. As to shifting this mould (in practice) so as to give the said angle-bracket its true back, there seems to have been enough said in plate P.

"Such things as the construction and use of lines, are not conceived by every one; therefore, because I would omit nothing that I think would prove useful, I have inserted several more examples of tracery, the knowledge of which seems indispensably necessary.

Figure 5. "That of T is a regular semicircle, as *a b c*, from which is traced the raking (or rampant) one U; that of W is a regular ellipsis, as *d e f*, from which is traced the raking one X; that of Y is a regular segment (or part of a circle) as *g h i*, from which is traced the raking one Z; the manner whereof being so plain, a farther explanation seems needless.

"As to the particular use of this kind of arches, I must leave to the determination of the curious, and have nothing farther to say on that head, than that if occasion require either of them to be executed, there is no other true way to describe them.

Figure 6. "That of F is a plan of circular groins, whose extent is *a b c d*, an example of which may be seen in St. Clement's Danes, Strand, and in several other circular buildings; and, in my opinion, is a curiosity worthy of regard. To find the plan of these groins, do thus: Divide from *a* to *b*, into a number of parts, as into ten; the lines *a b* and *d c* being continued, meet in a point as *g*, being the centre of the curves *a d* and *b c;* from which strike curves from the points in *a b* to *d c:* divide also from *a* to *d*, into ten parts, which being drawn to the centre *g*, divides the line *b c* into the same number of parts equally; so that the meeting of these lines is the plan of the groins, as *a e c* and *b e d*, and their upright is H, I, K, L, each being traced from the semicircle *a b f* in G, being the principal curve. As to the method whereby it is done, enough has been said of the foregoing examples to explain it; the letters of reference show plainly what part of the plan each curve belongs to, which being bent agreeable thereto, will strictly correspond with each other.

"N.B. If the principal curve had been a segment, or part of a circle, or an ellipsis, the method of performing would have been the same.

"This plan would be difficult in performance, if required to be ribbed with timber for plastering, but if to be centered for brickwork, it would be much easier; because the centres might be placed as from the line *a b* to that of *c d*, as in a common vault. The curves of each centre would be different, on account of its being taper, but the height is equal; these centres should be boarded as others are, the boards requiring to be taper only.

"To make groins so as to hang over the plan, the sides *a b e* and *c d e* must not be centered as usual; but have ribs agreeable to the plan, and placed horizontally, so that the boards would stand as it were upright; as in domes, which was explained in the foregoing plates, which shows the method for finding the curvilinear form of any ceiling.

"N.B. The foregoing must be well understood, in order to describe on the centres first boarded, the accurate curve of the groin; which can be done by no other method than is there shown.

"If this plan were to be executed with ribs of timber for plastering, then the groins must be performed by the methods, as will be hereafter inserted, for the twisted rails for staircases, on account of their plan not being a regular curve."

This method of constructing an annular groin, is of no other use than that of finding the seats of the lines of concourse of the meeting of the curved sides. It does not show how the boarding is to be formed geometrically, neither does it give the least idea of constructing the ribs of a plaster groin. The line of concourse of the two sides may be obtained by plumbing up from the base, but even this circumstance is not mentioned by Mr. Price, nor any other application of this construction. If it were required to construct the ribbing for a plaster groin, the method here shown is perfectly adapted to the formation of the ribs in thicknesses, as the whole of the ribs round the curves are extended in plano. But the glueing up of the ribs in thicknesses is altogether nugatory, when applied to the purposes of carpentry. Another mode, which we would propose, in order to bring this method into use in groin ribbing, is, to get the ribs cut into two thicknesses, say $1\frac{1}{2}$-inch stuff, and kerf each of them from one side; then put the two kerfed sides toge

ther, and nail or bolt them to the curve: to prevent them from extending before they are fixed, nail a temporary piece across the two extremities, and set them in their places; then when the other ribs are nailed against them, they will remain firm, and this without much trouble of construction. —In this operation, the kerfs must run in lines perpendicular to the base, otherwise they will not bend to the plan.

A TABLE FOR THE SCANTLINGS OF TIMBER.

A Proportion for Timbers for small Buildings.				A Proportion for Timbers for large Buildings.			
Bearing Posts of Fir		Bearing Posts of Oak		Bearing Posts of Fir		Bearing Posts of Oak	
Height	Scantling	Height	Scantling	Height	Scantling	Height	Scantling
if 8 feet	4 in. square	if 10 feet	6 in. square	if 8 feet	5 in. square	if 8 feet	8 in. square
10	5	12	8	12	8	12	12
12	6	14	10	16	10	16	16
Girders of Fir		Girders of Oak		Girders of Fir		Girders of Oak	
Bearing	Scantling	Bearing	Scantling	Bearing	Scantling	Bearing	Scantling
if 16 feet	8 in. by 11	if 16 feet	10 in. by 13	if 16 feet	9½ in. by 13	if 16 feet	12 in. by 14
20	10 12½	20	12 14	20	12 14	20	15 15
24	12 14	24	14 15	24	13½ 15	24	18 16
Joists of Fir		Joists of Oak		Joists of Fir		Joists of Oak	
Bearing	Scantling	Bearing	Scantling	Bearing	Scantling	Bearing	Scantling
if 6 feet	5 in. by 2½	if 6 feet	5 in. by 3	if 6 feet	5 in. by 3	if 6 feet	6 in. by 3
9	6½ 2½	9	7½ 3	9	7½ 3	9	9 3
12	8 2½	12	10 3	12	10 3	12	12 3
Bridgings of Fir		Bridgings of Oak		Bridgings of Fir		Bridgings of Oak	
Bearing	Scantling	Bearing	Scantling	Bearing	Scantling	Bearing	Scantling
if 6 feet	4 in. by 2½	if 6 feet	4 in. by 3	if 6 feet	4 in. by 3	if 6 feet	5 in. by 3½
8	5 2¾	8	5½ 3	8	5½ 3	8	6½ 3½
10	6 3	10	7 3	10	7 3	10	8 3½
Small Rafters of Fir		Small Rafters of Oak		Small Rafters of Fir		Small Rafters of Oak	
Bearing	Scantling	Bearing	Scantling	Bearing	Scantling	Bearing	Scantling
if 8 feet	3½ in. by 2½	if 8 feet	4½ in. by 3	if 8 feet	4½ in. by 3	if 8 feet	5½ in. by 3
10	4½ 2½	10	5½ 3	10	5½ 3	10	7 3
12	5½ 2½	12	6½ 3	12	6½ 3	12	9 3
Beams of Fir, or Ties		Beams of Oak, or Ties		Beams of Fir, or Ties		Beams of Oak, or Ties.	
Length	Scantling	Length	Scantling	Length	Scantling	Length	Scantling
if 30 feet	6 in. by 7	if 30 feet	7 in. by 8	if 30 feet	7 in. by 8	if 30 feet	8 in. by 9
45	9 8½	45	10 11½	45	10 11½	45	11 12½
60	12 11	60	13 15	60	13 15	60	14 16

Principal Rafters of Fir Scantling			Principal Rafters of Oak Scantling			Principal Rafters of Fir Scantling.			Principal Rafters of Oak Scantling		
Length	Top	Bottom	Length	Top	Bottom	Length	Top	Bottom	Length	Top	Bottom
if 24 ft.	5 in. & 6	6 in. & 7	if 24 ft.	7 in. & 8	8 in. & 9	if 24 ft.	7 in. & 8	8 in. & 9	if 24 ft.	8 in. & 9	9 in. & 10
36	6½ 8	8 10	36	8 9	9 10½	36	8 9	9 10½	36	9 10	10 12
48	8 10	10 12	48	9 10	10 12	38	9 10	10 12	48	10 12	12 14

"Although this table seems so plain as to need no explanation, it may not be amiss to observe some particulars, such as that all binding or strong joists ought to be half as thick again as common joists; that is, if a common joist be given three inches thick, a binding-joist should be four inches and a half thick, although the same depth.

"Observe also, that if conveniency do not allow of posts in partitions being square, in such cases, multiply the square of the side of the posts, as here given, by itself; for instance, if it be six inches square, then as six times six is thirty-six, consequently to keep this post nearly to the same strength, find some number that shall agree thereto; as suppose the partition to be four inches thick, then let your post be nine inches the other way, so that nine times four is thirty-six, being the same as six times six; so that the strength is nearly the same, although being equal in its squares is best for the strength.

"Posts that go the height of two or three stories, need not hold this proportion, because at every floor it will meet with a tie; admit a post was required of thirty feet high, and in this height there were three stories, two of ten feet, and one of eight. Look for posts of fir of ten feet high, their scantling is five inches square, *i. e.* twenty-five square inches; which double for the two stories.

"And take also that of eight feet high, being four inches square, *i. e.* sixteen square inches, all which being added together, make sixty-four square inches; so that such a post would be eight inches square. On occasion it may be lessened in each story as it rises.

"I do not insist that the scantlings of timber ought to be exactly as by this table is expressed, but may be varied in some respects, as the workmen shall see fit; the reason of its being inserted, is in consideration of the scantlings of timber, as formerly settled by act of parliament, and which, if compared, will prove the necessity and use of this table.

"As to plates on walls, or bressummers to support walls, I do not find they can come into any regular proportion, as the rest do, therefore must be left to discretion.

"And as I have herein described a great variety of the principal things requisite to be known by every carpenter, I shall conclude this part with my wishes that it may prove as useful as my earnest endeavours have been to make it so."

It is singular that in the foregoing table, the oak scantlings are greater than those of fir. Oak is more cohesive than fir, but fir is less compressible by forces acting in the direction of the fibres; oak is therefore more fit for ties, and fir for struts, or straining pieces. But Mr. Price, in this table, inconsiderately and indiscriminately makes the oak scantlings larger than those of fir.

The following observations, in the introduction to Price's work, are very judicious, and worthy of transcription.

"Nevertheless, it may not be improper, in this place, to mention some general observations. There is a moisture in all timber; therefore all bearing timber ought to have a moderate camber, or roundness: for till that moisture is in some sort dried out, the said timber will sag with its own weight; and that chiefly is the reason girders are trussed when used, as in its place will be shown. But here observe, that girders are best trussed when they are first sawn out, for by their drying and shrinking, it tightens the trusses in them yet more.

"Observe also, that all beams, or ties, be cut, or forced in framing, to a camber, or roundness, such as an inch in the length of eighteen feet; and that principal rafters be also cut, or forced up to a camber, or roundness, as before: the reason of this is, all trusses, though ever so well framed, by the shrinking of the timber, and weight of the covering, will sag, and sometimes so much as to offend the eye of the beholder; so that by this preparation your truss will ever appear well.

"Also observe, that all case-bays, either in floors or roofs, do not exceed twelve feet if possible; that is, do not let your joists in floors, your purlins in roofs, &c., exceed twelve feet in their length, or bearing; but rather let the bearing be eight, nine, or ten feet; which should be observed in forming a plan.

"Also, in bridging-floors, do not place your binding or strong joists above three, four, or five feet apart; and that your bridgings or common joists are not above ten or twelve inches apart, that is, between one joist and the other.

"Here also observe, never to make double tenants or tenons for bearing uses, such as binding-joists, common joists, or purlins; for, in the first place, it weakens very much whatever you frame it into; and, in the second place, it is a rarity to have a draught in both tenons, that is, to draw your joint close by the pin: for the said pin, by passing through both tenons, (if there is a draught to each,) must bend so much, that without the pin be as tough as wire, it must needs break in driving, and consequently do more hurt than good."

We are now come to Mr. Batty Langley, in whose numerous publications are to be found many particulars relating to Carpentry. In his *Builder's Complete Assistant*, published 1738, page 147, the fourth edition, he has the following observation:—

"When partitions have solid bearings throughout their whole extent, they have no need to be trussed; but when they can be supported but in some particular places, then they require to be trussed in such a manner, that the whole weight shall rest perpendicularly upon the places appointed for their support, and nowhere else. Partitions are made of different heights, to carry one, two, or more floors, as the kinds of buildings require.

"The first things to be considered in works of this kind are—the weight that is to be supported, the goodness and kind of timber that is to be employed, and proper scantlings necessary for that purpose."

So far his observations are tolerable; but his subsequent reasonings are drawn rather from his own caprice, than from the principles of science, as will be seen in the following quotations:

"The strength of timber in general is always in proportion to the quantity of solid matter it contains. The quantity of solid matter in timber is always more or less, as the timber is more or less heavy; hence it is, that all heavy woods, as oak, box, mahogany, lignum-vitæ, &c., are stronger than elder, deal, sycamore, &c., which are lighter or (rather) less heavy; and, indeed, for the same reason, iron is not so strong as steel, which is heavier than iron; and steel is not so strong as brass or copper, which are both heavier than steel. To prove this, make two equal cubes of any two kinds of timber, suppose the one of fir, the other of oak; weigh them singly, and note their respective weights; this done, prepare two pieces of the same timbers, of equal lengths, suppose each five feet in length, and let each be tried up as nearly square as can be, but to such scantlings, that the weight of a piece of oak may be to the weight of a piece of fir, as the cube of oak is to the cube of fir; then those two pieces being laid horizontally hollow, with equal bearings, and being loaded in their middles with increased equal weights, it will be seen that that they will bend or sag equally, which is a demonstration that their strengths are to each other as the quantity of solid matter contained in them."

This is reasoning only from conjecture, and therefore the consequence must be erroneous. The relation between weight and strength is not general. In some instances the very reverse takes place to what this author asserts.

"As the whole weight on partitions is supported by the principal post, their scantlings must be first considered, and this should be done in two different manners, viz., first, when the quarters, commonly called *studs*, are to be filled with brickwork, and rendered thereon; and, lastly, when to be lathed and plastered on both sides.

"When the quarters are to be filled between with brickwork, the thickness of the principal posts should be as much less than the breadth of a brick, as twice the thickness of a lath; so that when these posts are lathed to hold on the rendering, the laths on both sides may be flush with the surfaces of the brickwork. And to give these posts a sufficient strength, their breadth must be increased at discretion; but when the quarters are to be lathed on both sides, or when wainscoting is to be placed against the partitioning, then the thickness of the posts may be made greater at pleasure. The usual scantlings for the principal posts of fir, of 8 feet in height, is 4 or 5 inches square; of 10 feet in height, 5 or 6 inches square; of 12 feet in height, 6 or 7 inches square; of 14 feet in height, 7 or 8 eight inches square; of 16 feet in height, from 9 to 10 inches square. But these last, in my opinion, are full large, where no very great weight is to be supported. As oak is much stronger than fir, the scantling of oak-posts need not be so large as those of fir; and therefore the scantlings assigned by Mr. Price, in his *Treatise of Carpentry*, are absurd, as being much larger than those he has assigned for fir-roofs. To find the just scantling of oaken posts that shall have the same strength of any given fir-posts, this is the rule:

"As the weight of a cube of fir is to the weight of a cube of oak of the same magnitude, so is the area of the square end of any fir-post to the area of the end of an oaken post, and whose square root is equal to the side of the oaken post required."

He might as well have asserted, that as the weight of a cube of steel is to the weight of a cube of lead, so is the area of the square end of any steel bar to the area of the end of any leaden bar; which proposition would have led to manifest falsehood. In the rule he has not mentioned the length, which, if taken into the consideration, would bring a very

different result; as timber is considerably weakened by its length. The rule is therefore not only erroneous, but defective also.

With respect to Mr. Price's table, we have only to observe that as there are no details of experiments on the strength of oak and fir, when employed as posts, we cannot decide in this matter. It must, however, be observed, that the fibres of fir are straight, whilst those of oak are very crooked; whence it is reasonable to conclude that a body with straight fibres is better adapted to resist compression than one whose fibres are crooked; and this supposition is strengthened, if not confirmed, by the experiments of Muchenbreuk, who asserts, that though oak will suspend half as much again as fir, it will not, as a pillar, support two-thirds of that load. Now if we can put any dependence on these experiments, fir should be used in cases of compression, as in story-posts, partitions, &c., and oak in cases of tension, as ties, truss-posts, &c.

"The distances of principal posts are generally about ten feet, and of the quarters about fourteen inches; but when they are to be lathed on both sides, the distances of the quarters should be such as will be agreeable to the lengths of the laths, otherwise there will be a great waste in the laths. The thicknesses of ground-plates and risings are generally from two inches and a half to four inches, and are scarfed together."

With respect to lintels, bond-timbers, and naked flooring, he observes as follows:

"For the better disposing of the weight imposed on girders, lintels should always be firmly bedded on a sufficient number of short pieces of oak, laid across the walls, vulgarly called *templets*, which are of excellent use.

"Let girders be laid in piers, or in lintels over windows; it will in both these cases be commendable to turn small arches over their ends, that in case their ends are first decayed, they may be renewed at pleasure, without disturbing any part of the brickwork; and for their preservation, anoint their ends with melted pitch and grease, viz., of pitch four, of grease one; and, indeed, were lintels to be covered with pitch and grease also, it would contribute very greatly to their duration.

"In the carrying up the several walls of buildings, it should be carefully observed, to lay in bond-timbers on templets, as aforesaid, at every six or seven feet in height, cogged down and braced together with diagonal pieces at every angle, which will bind the whole together in the most substantial manner, and prevent fractures by unequal settlement.

"The distances of girders should never exceed twelve feet, and their scantlings must be proportioned according to their lengths; as by experience it is known that a scantling of 11 inches by 8 inches is sufficient for a fir-girder of 10 feet in length, the area of whose end is 88 inches, it is very easy to find the proper scantling for a girder of any greater length, suppose 20 feet, by this rule: As 10 feet, the length of the first girder, is to 88, the area of its end, so is 20 feet, the length of the second girder, to 176, the area of its end.

"Now to find its scantlings, that, being multiplied into each other, shall produce 176 inches, the area found, one of them must be given, viz., either the depth or thickness. In this example, the given depth shall be 12 inches, therefore divide 176 by 12, and the quotient is 14 inches and two-thirds, which is the other scantling, or breadth required."

In this example, the length is regarded; but in the first instance, in the dimensions of the given piece, he does not say which of them is the depth. This should have been noticed, as the strength of a piece of wood with its greater dimension disposed vertically, is to the strength of the same piece with its less dimension in the same position, as the greater dimension is to the less. Another uncertainty will arise from the proportion; for if the scantlings are not in the same ratio, the strength will be more or less in the one, as the vertical dimension may be greater in proportion to the horizontal than those of the other piece. Mr. Langley should have noticed this also. He has assumed 12 inches as the depth, then finds the breadth to be 14 inches and two-thirds, by dividing 176 by 12; but this is only guessing at the proportion, which might be properly stated by the rules of algebra, as follows: What two numbers are those, whose product is 176, and whose proportion is in the ratio of 11 to 8? Take x for the greater, and y for the less of the two numbers; then we have

$$xy = 176$$
$$x : y :: 11$$
$$8x = 11y$$

From the first equation we have

$$x = \frac{176}{y}$$

and from the second,

$$x = \frac{11y}{8}$$

Therefore,

$$\frac{11y}{8} = \frac{176}{y}$$
$$11y^2 = 1408$$
$$y^2 = 128$$

consequently, $y = (128)^{\frac{1}{2}} = 11.3$ nearly; and by dividing by 11.3 inches, the depth, we should then have the breadth. We have here taken it for granted, that the former part of his proposition is true, but, indeed, nothing can be more erroneous; for their lengths are not in the ratio of the areas of their sections, when the pieces are of equal strength, but their lengths are in the ratio of the breadth multiplied into the square of the depth; or if their sections be similar figures, the lengths will be in the same ratio as the cubes of their vertical dimensions. By this method, if two pieces of timber were of the same thickness, and of equal strength, the lengths would be as the depths; whereas they are as the square of the depths. So that, besides the ambiguity of his rule, allowing the data to be properly fixed, the results would give the dimensions of the section much too great, in calculating from a given beam of less length to one of a greater; and much too small in calculating from a greater length to a smaller one. In calculating the strength of beams, it is material to recollect the loss of strength in large beams, occasioned by their weight, as the strength of beams is not in the same ratio with the stress occasioned by their weights, but in a much less degree: but as we shall hereafter discuss this subject, under the article STRENGTH OF MATERIALS, we shall for the present take leave of the subject, and return to our author.

"To prevent the sagging of short girders, it is usual to cut them camber; that is, to cut them with an angle in the midst of their lengths, so that their middles shall rise above the level of their ends, as many half inches as the girder contains times ten feet. And, indeed, girders of the greatest length, although trussed, should be cut camber in the same manner."

It may be proper here to notice, that the cambering of girders does not prevent them from sagging, though perhaps it may obviate their becoming concave on the upper side. With regard to trussing girders, the flitches should not be cut to a camber, but brought into this state in the act of trussing.

"The next order is joists, of which there are five kinds, viz., common-joists, binding-joists, trimming-joists, bridging-joists, and ceiling-joists. First, common-joists are used in ordinary buildings, whose scantlings in fir are generally made as follows, viz.:

Common joists, as used in small buildings.	
Length in feet.	Scantling in inches.
6	$6\frac{1}{2}$ by $2\frac{1}{2}$
9	$6\frac{1}{2}$ by $2\frac{1}{2}$
12	8 by $2\frac{1}{2}$

In this table, it may be observed, the increase is not very regular: why should the scantling of the joist 9 feet in length, be no more than that of 6 feet? This must be a mistake

"But in large buildings, the scantlings are much larger, where it is common to make joists of the following dimensions:

Common joists, as employed in large buildings.	
Length in feet.	Scantling in inches.
6	5 by 3
9	$7\frac{1}{2}$ by 3
12	10 by 3

"As oak is much heavier than fir, it is customary to make the scantlings of oak-joists larger than those of fir; but I believe it to be entirely wrong, for the reason before given, relating to the strength of timber.

"Secondly, binding-joists are generally made half as thick again as common-joists of the same lengths;" and "are framed flush with the under surface of the girders, to receive the ceiling-joists, and about 3 or 4 inches below their upper surfaces, to receive the bridging-joists; so that the upper surfaces of the bridging-joists may be exactly flush or level with the girder to receive the boarding.

"The distances that binding-joists should be laid at, should not exceed 6 feet, though some lay them at greater distances, which is not so well, because the bridging and ceiling-joists must be made of larger scantlings to carry the weight of the ceiling and boarding, and consequently a greater quantity of timber must be employed. But, however, as this particular is at the will of the carpenter, I shall only add, that the scantlings for bridgings of fir, to their several lengths, are as follow:

Bridgings of fir.	
Bearing.	Scantling.
feet.	inches by inches
6	4 by 3
8	5 by 3
10	7 by 3

"Their distances from each other, about 12 or 14 inches."

He then proceeds with roofs, as follows.

"As the common method of framing the trusses of principal rafters of large roofs, is to lay the whole weight of the beam and covering upon the feet, they therefore should be secured at the beam with iron straps, to prevent their flying out, in case that the tenons should fail; but as I apprehend this method was capable of improvement, I therefore considered, that if under the lower parts of principal rafters, there be discharging struts framed into the beams and pricked posts, they will discharge the principal rafters from the greatest part of the whole weight."

This is certainly an improvement, but not of his, as it is to be found in Price's *Carpentry*, among his designs of roofs; it gives an additional security to the principal rafters, so that if the outer abutment should fail, the roof will still be supported by the inner one.

He gives the scantlings of fir-timbers in a roof, as follows:

Beams.	
Length.	Scantling.
feet	inches by inches
30	6 by 7
45	9 by 7
60	10 by $8\frac{1}{2}$
75	$10\frac{1}{2}$ by 10
90	12 by $10\frac{1}{2}$

Principal Rafters.		
Length.	Scantling at Top.	Scantling at Bottom.
feet.	inches by inches.	inches by inches.
24	5 by 6	7 by 6
36	7 by 6	9 by 7
41	9 by 7	10 by $7\frac{1}{2}$
60	10 by $7\frac{1}{2}$	10 by 9
72	10 by 9	11 by $9\frac{1}{2}$

Small Rafters.	
Length.	Scantling.
feet.	inches by inches.
8	$4\frac{1}{2}$ by 3
10	5 by 3
12	6 by 3

Besides the formation of the end of a purlin, attempted by Price, Langley also notices the bevels of the jack-rafters. We now come to the description of his diagrams.

"The *Figures* 1 and 2, *Plate* 9, are examples of floors made of short lengths, which I have given for the diversion of the curious."

These floors are of a similar construction with those shown in the works of Dr. Wallis. Godfrey Richards, our first author, has also inserted two kinds of floors of this nature, one constructed of hexagons and triangles, the other consisting of squares laid diagonally in respect of the plan, with a hexagon in the middle. These examples were executed at the old Somerset House, and were at that time a novelty in England. This species of naked flooring may be seen in the works of Serlio. It had its origin in Italy, and was thence transported to this country. Though from the principles of construction, the timbers mutually support each other, this species of joisting has not been found advantageous, either in saving of expense, or with respect to strength, but the contrary; it has therefore in modern works been discontinued.

Figure 3, "represents the section of a girder; *b b*, &c., parts of two binding-joists, tenoned into the girder; *a a*, &c., the ends of bridging-joists; *e e*, boarding on the bridgings; *d d*, &c., mortises in the binding-joists to receive the tenons of the ceiling-joists; as also the mortises *b c*, *b c*, &c., but these last are those which are called *pulley-mortises*, into which the ceiling-joists are slid. To understand this more plainly, (see *Figure* 4,) the figures *f f f f* are added, which represent the sections of so many binding-joists; *g g*, &c., the sections of small joists between them; *x x*, a side view of a bridging-joist; *h h h*, ceiling-joists tenoned into the binding-joists, flush with their bottoms, as aforesaid, to receive the lath and plaster."

Figures 5 and 6 are parts of *Figures* 3 and 4, enlarged.

The joists *g g*, in *Figure* 4, add considerable expense, without being of adequate service.

Figures 7, 8, 9, 10, are scarfings shown in plate 50, of his work; but he takes no notice of them in the text, and indeed they are not deserving of it; we have already noticed those in Smith's work, to which these of Langley's have a near affinity.

Figure 11, represented in plate 53 of his work, is not noticed in the text, but the following words are written over the top of the figure: "A new method for trussing-beams, girders, &c., by Batty Langley."

The showing of such ridiculous constructions in carpentry, has certainly lessened the credit of this author, as permitting fancy to take the place of judgment, in cases where strength alone was the object.

Figure 12 is his method of laying roofs in ledgement; he only differs from Price in this particular, that he lays all the rafter feet next to the wall-plates, whereas Price lays them the contrary way. Price's disposition is more convenient in practice, but Langley's more natural for building up.

Figures 13 and 14 are his methods of tracing angle-brackets, and are the same in principle as that shown by Halfpenny, which was an example for a right angle. But Langley, always profuse in his figures, and pompous in his text, has not only shown the description of angle-brackets for right angles, but also for obtuse and acute angles, likewise for ovolos, cavettos, cimarectas, and cima-reversas, as if the same principle did not apply to all forms alike.

In *Figure* 15, his description is as follows: "The curvatures of hip-rafters to polygonal roofs, that is, those whose plans are polygons, are also found by transposing the ordinates of a principal rafter (which must be given) upon the base of a hip-rafter.

"Suppose in" (*Figure* 15) "*a d* to be the base, over which the cavetto principal rafter *c d*, is to stand: and let *a e* be the base of a hip-rafter: divide *a d* into equal parts, and draw the ordinates 2, 1; 4, 3, &c., on the line *a d;* divide *a e* in the same manner as *a d*, and on the line *a e* draw the ordinates 1, 2; 3, 4; 5, 6, &c., and from the point *b*, through the points 2, 4, 6, 8, &c., trace the curve of the hip-rafter, as required."

This disposition of confining the parts into one connected diagram is more obvious to learners than Mr. Price's, but even this of Langley's is not shown to the utmost advantage; for why divide the bases into equal parts, as this equality causes the curvature of the ribs and the curving sides of the covering to be divided unequally? Though the covering is shown in the figure, he has given no description of it in the text.

Figure 16, shows his method of covering niches or domes, explained as follows: "Let *a f c* be the plan of the head of a semi-circular niche, and complete the circle *a f c d*. Draw the diameters *a b c* and *d b f* continued out towards *e* at pleasure. Make *f r* and *f s* each equal to one-fourth of *a f;* then *r s* will be equal to half *a f*, and draw the lines *r b* and *s b*, divide *b d* into any number of equal parts, and draw the ordinates 1, 8; 2, 9; 3, 10, &c., and on the points where those ordinates cut the semi-diameter *b d*, with the radius of each semi-ordinate, describe semi-circles, as the dotted semi-circles in the figure. Make *e f* equal to the curve *a f;* make *f p* equal to *a* 1; *f o* equal to *a* 2; *f n* equal to *a* 3; *f m* equal to *a* 4; *f l* equal to *a* 5; *f k* equal to *a* 6; and *f g* equal to *a* 7. On the point *e* describe the arches 13, 14; 11, 12; 9, 10; &c. Bisect the half part of each of the dotted semi-circles, as *f c* in one; 1, 8, in two; 3, 9, in four; 5, 10, in six; 7, 11, in eight; 9, 12, in ten; 11, 13, in twelve; and 13, 14, in fourteen; make *f h* and *f g* each equal to half the arch *f i;* *p* 1 and *p* 2 each equal to half the arch 1, 2; *o* 3, *o* 4, each equal to half the arch 3, 4; and so, in like manner, *n* 5 and *n* 6, to the half arch 5, 6, &c. From the point *e*, through the points 12, 11, 9, 7, &c., and 14, 12, 10, &c., trace the curves *e h* and *e g;* then four such pieces as *e g h* will cover the head of the niche, as required."

This is certainly a very tiresome method, as each of the semi-circles must be divided into equal parts; but why divide each quadrant into two, which he has directed? as the more the parts, the truer the covering will be. If the arches *a d* and *c d* had been divided into equal parts, the covering could have been traced with more exactness, as there is a very long space beginning with the point *e*, without any guide, and is as much as the three lower spaces taken together: an equality of the parts in *a d* and *c d* would have been productive of the parts *e g*, *g k*, *k l*, &c., also equal to each other, and consequently the distances of the points in the curves *e h* and *e g*, though not exactly equal, would have been nearly so.

The description given by Mr. Price for the covering of domes, is defective; but his aim was at a much more convenient method than this of Langley's, which requires ample space, and is very troublesome and tedious in practice, without obtaining any greater accuracy. The reader must observe, that in strictness of principle, no flat surface, however thin, can be made to comply with a spheric surface; yet if comparatively a very small portion of the flat surface be taken, it may be made so nearly to coincide with the spheric, as not to be detected by the eye, which is as near as we ever need in practice; and thus the narrower the board, the more nearly will its surface comply with the spheric surface; but as we shall have occasion to speak of this in another place, we shall leave it for the present, and proceed to show his methods of finding the coverings of solids.

Figure 17, "represents the manner of covering the outside of a cone; the arch *e a* being made equal to the circumference *e*, which is equal to the base of the cone: this figure is exhibited here to show, that the soffits of a semi-circular headed window, whose splay is continued all round, is no more than the lower superfices of a semi-cone; for if the splay were continued, it would meet in a point."

In this respect he is right; but no covering can be more easy to conceive, except that of a right cylinder. The method of covering an oblique cylinder he never could obtain, as the edges which should coincide with the elliptic sections are all exhibited in straight lines. See Plate 74, at the end of nis *Builder's Complete Assistant;* neither has he ever been able to obtain the covering of the ungula of a right coue, or of its complement when cut to produce an elliptic section, so that the edge of his covering may coincide with the said elliptic section, and its surface with the curved surface of the cone.

Figure 18. "The superficies of these frustrums are laid out

as follows." "On *a* describe the arch *c m l*, &c. *e* equal to the circumference of the base of the cone, which divide into eight equal parts, at the points *m*, *l*, *k*, *i*, &c. and draw the lines *a m*, *a l*, *a k*, &c. Draw *b* 1, parallel to *d c*, and divide *i c* into four equal parts. Make *a* 5, *a* 11, each equal to *a* 4; make *a* 6, *a* 10, each equal to *a* 3; make *a* 7, *a* 9, each equal to *a* 2; make *a* 8 equal to *a* 1. Through the points 11, 10, 9, 8, and 7, 6, 5, trace the curves *e* 8 and 8 *c*; then the figure *c* 8 *e i c* is the superficies of the side."

What has the division of the line *i c* to do with the principle? This equality is not founded upon any part of the construction of the solid, and consequently the method can never obtain a true cover or envelope; indeed, it is so void of science as not to deserve any farther notice. In the next place, he attempts to find the envelope of a part of a semi-cuneoid, contained between two concentric cylindric surfaces, or of the covering or lining of the soffit of a window turned upon a centre, which has either an elliptic or circular section, everywhere parallel to its end, and to coincide with the superficies of a circular wall, or the head of an aperture splaying on the sides, and level at the crown. But are we now to expect that this will be accomplished, unless by accident, when he has already failed in obtaining methods for the description of much more simple envelopes, viz. for cylinders and cones cut obliquely? The reader will, however, attend to his description, which is as follows, and then judge for himself.

The descriptions of the following diagrams are equally deficient in method, and void of principle: his diagrams, also, are full of redundant lines. He begins the text without announcing the purpose of the operation, so that the reader must be kept in the dark till the conclusion.

Plate X. *Figure* 1. "*Of straight, circular, and elliptical arches in circular walls.*—The first work to be done, is the making of the centres, to turn these kinds of arches upon, which may be thus performed: Let G H I K be the plan of a circular building, and at *Figure* 6, it is required to make a centre for a semi-circular arch to the window, whose diameter without is *a d*, and within *n m*. Bisect *a d* in *f*, and describe the semi-circle *a p d*. Divide *a d* into any number of equal parts at the points 6, 4, 2, &c. and draw the ordinates 6 6; 4, 4; 2, 2, &c. Divide *n m* into the same number of equal parts, and make the ordinates 6, 5; 4, 3; 2, 1, &c. equal to the ordinates 6, 6; 4, 4; 2, 2, &c. and through the points 5, 3, 1, *k*, &c. trace the curve *n k m*, then *a p d* and *n k m* will be the two ribs for the centre: this being done, place the ribs perpendicular over the lines *a d* and *n m*, and cover them, as centres usually are, and then, applying the edge of a plumb-rule to the divers parts of the inside and outside of the window's bottom, the top of the rule will give the several points at which the inside and outside of the covering is to be cut off, so as to stand exactly over the inside and outside of the building, and then the centre will be completed as required."

It is hardly possible to conceive anything so unscientific as this description. In describing and forming the centre for the head of the required aperture, he is accurate; but when we are told to apply "the edge of a plumb-rule to the divers parts of the inside and outside of the window's bottom," and that "the top of the rule will give the several points at which the inside and outside of the covering are to be cut off, so as to stand exactly over the inside and outside of the building; and" that "the centre will be completed as required," he is altogether intolerable; for besides being tedious to an extreme, it is no more than every mechanic could have easily conceived. In forming the centre, it would be better to form the inside curve with a trammel, which would obviate the tedious work of dividing the base of each curve into equal parts, as well as the transferring of the ordinates of the semi-circle to those of the ellipses, and then, at last, either tracing the elliptic curve by hand, or bending a thin slip of wood round pins or nails stuck in the points. At all events, even in the operation of tracing, the dividing of the bases into equal parts is a very bad practice, as it always leaves so large and so quick a portion of the curve at each extremity to be guessed at; but here it is admissible, on account of the following diagrams connected therewith.

"*To divide the courses in the arch of this window.*—On a flat panel, &c. draw a line, as *b e*, in *Figure* 7, make *a f o* equal to the curve *a c d*, also make *a b* and *o e* each equal to the intended height of the brick arch. Make *f p*, in *Figure* 7, equal to *f p*, in *Figure* 6; also make *a b* and *o e*, in *Figure* 7, each equal to *b a*, in *Figure* 6; then the points *b* and *e* will be the extremes of the arch. Make *p r*, in *Figure* 7, equal to *b a*, the given height of the arch, and through the points *b r e* and *a p o* describe two semi-ellipses, which divide into courses as before taught, and which will be the face of the arch required."

This operation produces nothing, as he does not show its application to practice, in the formation of the stones or bricks to their proper shapes.

"*To find the angles or bevels of the under part of each course.*—Continue the splay backs of the window *m d* and *n a* until they meet in F. On F, with the radius F *n* and F *a*, describe the arches *n y v* and *a f s*, making *n y v* equal to the girt of the arch *n k m*. Make *n* 6, *n* 4, *n* 2, *n y*, &c. on the arch *n y v*, equal to *n* 6, *n* 4, *n* 2, *n y*, &c. on the curve *n k m*, and draw the lines 6 F, 4 F, 2 F, *y* F, &c. Make the ordinates 6, 5; 4, 3; 2, 1; *y x*, &c. on the lines 6 F, 4 F, &c. equal to the ordinates 5, 6; 3, 4; 1, 2; *h i*, &c. on the line *n m* and through the points 5, 3, 1, *x*, &c. trace the curve *v x n*. In the same manner transfer the ordinates 5, 6; 3, 4; 1, 2; *c f*, &c. on the line *a d* to the arch *s f a*, as from 5 to 6, from 4 to 3. &c. and trace the curve *s c a*; and then will the figure *n x v s c a* be the soffito of the window laid out, and which being divided into the same number of equal parts, as the under part of the arch *a p o*, *Figure* 7, and lines drawn to the centre F, as is done in *Figure* 2, to the centre A, by the line 2, 2, 2, &c. those lines will give the bevel of every course in soffito, as required."

Here is an attempt to find the lining or envelope of a cuneoid or cono-cuneus, in a circular wall, for the soffits of the stones or bricks; and had he succeeded, his endeavours would have been so far right: but the method which he follows has no relation to the construction of the centre itself, and is therefore extremely erroneous. Nor can the same method be applied to the covering of a cone, though the affinity or relation is much nearer in the latter solid than in the former, and, consequently, the envelope here found would cover a cone more nearly than the surface of a cuneoid. But, indeed, though very near approaches have been made to the cuneoidal surface, its determinate figure has never been exactly shown on a plane: however, the geometrical construction may be laid out on the surface of the solid itself, and all curves, corresponding to given ones on the plan, found with the utmost accuracy. The other parts of *Figure* 7, are not described in the text, but seem to contain lines without meaning. The following is all that is said of *Figures* 1, 2, 4, and 5:

Figure 5 "is another example of a semi-elliptical arch, whose front is *Figure* 2. Also *Figure* 4, is a third example of a scheme arch, whose front is *Figure* 8. And *Figure* 1, is a fourth example of a straight arch, which, in general, are performed by the aforesaid rule."

Here the text is unintelligible, and the discovery of the principles, by inspection, still more so.

Passing from the *The Builder's Complete Assistant*, we come next to *The Builder's and Workman's Treasury of Designs*, by the same Author. The portion of this work which treats of carpentry, is contained in an appendix at the end, consisting of fourteen plates.

In *Plate* XI. *Figures* 1 and 2, Nos. 1, 2, 3, of each Figure, are shown two methods of lengthening beams: but there is no other description than what is exhibited at the top of the plate, viz., "The splicing or lengthening of beams explained."

The two pieces are tabled together, by a very different method to what any former author has exhibited. The tables are concealed, showing on the outside, when bolted together, as in No. 3 of each Figure, an oblique continued joint. The construction is ingenious, as it prevents their separation without breaking the tables by a longitudinal strain; but the difficulty of fitting them together with accuracy, and the tedious process, renders them unfit for practice.

Langley's *Geometrical Principles of Roofing* are similar to those of the preceding author; but for the sake of showing the terms applicable to different purposes, and his method of treating the subject, we shall extract a few of his descriptions: "$abcd$ (*Figure* 3) plan of the raising; ef the central line; im, lo, base lines of the outward principals, ag, gc, bh, hd, base lines of the hips; gh base of the ridge; kn base line of the middle pair of principals; eg, hf, base lines of the single principals, which meet the hips in the points gh; ikl, mno, dovetail mortises in the raising, to receive the *dovetails* or *cauks* 1, 2, 3, of the beams A B C; (*Figure* 10) pp, dovetail mortises to receive the *angle-braces*, as p, p. *Figure* 4. D, a cauk or dovetail at large; E, the dovetail-mortises in the raising, to receive the dovetail or cauk D."

Figure 4. "$abcd$, plan of the raising; fg, fg, fg, beams *cauked* down on the raising; pp, pp, &c., *angle-braces cauked* down in like manner; ae, be, ce, de, *dragon-pieces* to receive the feet of the hip-rafters; ah, bh, ch, dh, hip-rafters; ahk, the angle at the top; and hak the angle of the foot of the hip ah."

Figure 5. "*To find the angle of a hip in any regular or irregular building.*—RULE. On any part of its base line, as c, draw a right line at right angles, as fg; set up the hip, as hb, and from c draw cd perpendicular to the hip hb; make ce equal to cd, and draw the lines fe, eg; then the angle feg is the angle of the back required."

These descriptions are tolerably clear; the technical terms used by him, are *raising*, *base-line*, *hips*, *back of the hip*, *principals*, *dovetail-mortises*, *cauks*, *angle-braces*, and *dragon-pieces*. *Raising* is used by Moxon, in his *Mechanical Exercises*, but is vaguely defined by that author; *base-lines*, *hips*, *back of the hip*, and *principal rafters*, are used by Godfrey Richards, in his *Constructions of Roofs*, in finding the lengths and backings of hip-rafters. This last-mentioned author names the diagonal beams under the hips, *dragon-beams*; Langley calls them *dragon-pieces*. What Langley spells *cauks*, Price spells *cocks*. *Angle-braces* are not, that we have observed, named by any author before Langley, who also names *jack-rafters*, in Plate 5, of his *Builder's and Workman's Treasury*.

There is a work, not mentioned in the list of authors, by Edward Oakley, Architect, which, in point of priority, ought to have stood even before Smith's *Carpenter's Companion*, it being dated in the title-page 1730: another work was likewise published by Edward Hoppus, Surveyor, the second edition of which, as appears from the title-page, was published in 1738; when the first edition was published we do not know, but probably about the same time as Oakley's, or before. With respect to carpentry, these two works are nearly alike, as to the number of the problems, their order, the method of treating them, and the end intended; one seems to have been copied from the other, and the first of the two to have been taken from Halfpenny's *Art of Sound Building*, with the exception of a problem, which is exhibited in a plate, and explained in each of these authors, for covering of the head of a niche or dome, with boards, to bend with their joints in vertical planes, passing through its axis. This problem is thus explained by Oakley:

Figure 6. "*To make a niche or globe, with thin boards, or to cover them with paper or pasteboard.*—Admit afl (No. 1) to be the plan of a semi-circular niche; $cefd$ (No. 2) to be the board, paper, or pasteboard, of a given width, cd or ef. Divide the semi-circle afl into equal divisions, according to the breadth of (No. 2) as ab, bc, cd, de, eg, gh, hi, ik, and kl; draw the lines, bu, cu, du, eu, gu, hu, iu, ku, and let fall perpendiculars on the line al, from the points b, c, d, e, g, h, i, k. Upon the centre u, with the intervals, m, o, r, and t, describe semi-circles; set the girt of the arch af or fl, on the board, gc, (No. 2) as ca and db, which divide into so many equal parts as there are semi-circles; as in (No. 2.) Divide (No. 2) in the midst, as by the line uw; take the arch ab, and set it equally on each side of the line uw, as at ab; set the arch mn, in like manner, on uw, as at mn, and so on to ts; then by sticking in small tacks at the points a, m, o, r, t, and u, on the one side of uw, and at the points b, n, p, q, and s, on the other side of uw, by applying a thin ruler from a to u, and b to u, the curve lines on each side will be given, which may be described by a pencil, &c., which is the true mould for every piece in a globe or niche, which was required."

Here it must be observed, that the division of the semi-circle (No. 1) is erroneous; for if the quadrant af or fl be considered as a vertical section of the dome, it is evident it should have been divided into the same number of parts as the length of the board (No. 2;) and the several lengths of the one equal to those of the other; but af or fl is only divided into $4\frac{1}{2}$ equal parts, while the board is divided into 5; which inequality causes the board to be too narrow towards the top, and to swell out too much at the bottom, as shown in the following figure.

In *The London Art of Building*, written by Salmon, there is nothing new in construction. His geometrical principles of roofing are like those by Godfrey Richards; besides which, he treats of no other subject, except a few designs of roofs.

The British Architect, the production of Mr. Abraham Swan, is not very abundant in curious constructions of carpentry, yet there are some ideas worthy of notice.

Figure 7, No. 1, "Shows the backing of the hip." "Divide the thickness of the hip into two equal parts; then having found the pitch of your hip, as is shown in (No. 2) set one of these parts upon the base line, from b to a, and it shows what wood is to be taken off.

"If the side of the building comes in with a bevel, as the dotted line h, in (No. 1) then transfer half the thickness of the hip, from d to c, in (No. 3) and take the distance fe, in (No. 1) and set it from c to g, in (No. 3.) This will show how much is to be taken off the hip, when the building bevels."

It is strange that this author should have departed so far from Pope's scientific method, as first shown by Godfrey Richards, in order to adopt one so mechanical, more liable to inaccuracy, and less expeditious.

With respect to groins, all that Swan has said on this subject, is contained in the following words:

Figure 8, "exhibits an arch boarded over, wherein the several figures 1, 2, 3, &c., represent so many ribs, or jack-rafters, set upon the circular body of the arch, in order for another arch to intersect it, where those boarded over the groins are formed." We learn nothing from this, but the manner of placing the jack-ribs on the body of the arch. Price describes the method of placing these low ribs upon the boarding, and calls them *small centres;* but his diagram is different, and not near so clear.

In the boarding of domes with the joints in horizontal planes, Swan has shown the first ideas of the subject: *Figure* 9, "represents a circular body. *To find the curve of any lath or margin to be bent round this body, parallel to its base.*

"Let the points *b* and *c* represent the margin which you intend to bend round; then draw a right line through these points, to meet the perpendicular or diameter produced, as in *a*, and it gives the length *a b* the shorter, and *a c* the longer radius for striking the curve required."

This author has nothing more of novelty in the art of carpentry.

Our next author is Mr. William Pain. In his *British Palladio*, he shows the methods of his bracketing for coves, and plaster cornices, as follows: *Plate* XII. *Figure* 1, "D is an angle-bracket for an internal angle, which are (is) traced by ordinates." *Figure* 2, "E is an angle-bracket for a plaster cornice, at an internal angle; F, an external angle, allowing one inch for lath and plaster." The formation of angle-brackets is so easy, that a very little reflection, on inspecting the figure, will show the method adopted, without description: but still something more might have been said on the practical part.

From *The Builder's Golden Rule*, the following diagrams, with their descriptions, are taken. "*The backing of curve-line hips, and tracing them.—Figure* 3, (No. 1) is the rib of a dome, and (No. 2) is the hip traced from it. Divide the given rib (No. 1) into five parts, on the base line, and draw the ordinates 1, 1, 2, 2, 3, 3, 4, 4, 5, 5; then divide the base line of the hip into the same number of parts; take them from (No. 1) and set them on (No. 2); then tack in nails at the points 1, 2, 3, 4, 5; bend a thin slip round, and mark as that curve directs, which gives the hip-mould. To back the hip, take from (No. 3) the plan of the hip, 1, 2, and set it on the hip at the bottom 1, 2; then shift the hip-mould to 2, and out to the top: mark it by, and that will be the wood to come off for the backing of the hip." The practice of dividing the base of the given rib, and the base of the required rib into equal parts, was first shown by Halfpenny, and now by our present author, Pain; and though the principle is true, the practice is bad, as it leaves so great a portion of the curve to be traced by the eye, where it rises from the base; and though it is not necessary that each base should be divided into equal parts, or into any series of parts which shall have a given proportion to each other, yet it would be better to divide the curve of the given rib into equal parts, then divide the base of the required rib in the same proportion; and the arcs of the required rib terminated by the upper extremities of each two ordinates, will be very nearly, if not quite, proportional; that is, the distance between the tracing points will be nearer where the curve is quickest, and where the greater number of points are most required.

Figure 4, shows "the backing for a straight hip. You are to observe that the piece of wood be of the same thickness as the hips, and form of the curve, for the little part you want; then cut it to the pitch of the hip at foot, set it on the plan, and mark it by that, which will give the backing exactly; and so for any other. Or, if you draw a line parallel with the base line, and take off 1, 2, on the plan (No. 2) and set it on the said lines 1, 2, all the way up; and mark by the mould, it will give the backing in any case required, straight or curved."

This general and correct principle was first noticed by Price.

Figure 5. "*The method of coving the angles, when there is a circle or oval in the centre of the ceiling.*—Draw the centre part, touching the sides and ends; then draw another to the extreme of the angles, parallel with the centre; then draw the semicircular arch A, and from that trace the side arches B, B, and the rib C, C, C, C, which is a mould to cut all the brackets for the angles; as is plain to inspection by the lines on the plan."

This principle is erroneous, and the description deficient. There is no respect paid to the elliptic base; but the brackets are traced upon the principle of angle-brackets. The sections of any body must depend upon the construction of that body, or upon its properties; thus, if a body is intended to have this property, that all parallel sections are to be similar figures, and if the method of forming it is not founded upon this principle, the body is not what it was intended to be, but something else; the construction will therefore be erroneous. All sections of a body must be found by describing the seats of the curves of as many parallel sections as may be thought sufficient, on one of the largest of them; then having a given or transverse section, that will cut all the parallel sections of the body, all other sections whatever may be found: but our author, Mr. Pain, forms the section of all bodies like those of prisms, without attending to the properties of the body required, as is the case in the example before us.

In the first edition of his *Practical House Carpenter*, he has presented the diagram of an interior circular dome, formed into pendentives by bracketing the spandrels above, and traced according to the same erroneous principle: but after the publication of the *Carpenter's New Guide*, by the author of this Work, the error was corrected, in the second edition of the said *Practical House Carpenter*, so as to correspond with the legitimate principle, first published in the *Carpenter's New Guide:* his description, which is very short, is partly contained in the text, and partly on the plate: in the text, he says, *Figure* 6, "is a conical skylight, showing how to bracket the angles of the ceiling under the kirb, the hip-mould *g* at the angle is traced from the rib *b*, and that mould would do to cut all the ribs at the angles, as shown at the angle *a*."

What is here said, refers to the diagrams in the first edition; but the text stands in the sixth edition, as in the first, though the diagram is altered in the second and succeeding editions. There is no rib *b*, nor angle *a*, shown on the improved diagram. On the plate he writes thus: "F dome with a skylight on the top. *g*, *g*, moulds for the ribs of the dome; *a*, *a*, the kirb of the light." This latter description refers to the diagram as it now stands.

The skylight on the top is exhibited in a very erroneous manner, being inconsistent with the principles of any kind of projection that we are acquainted with. The plan of the bracketing, and the ribs of the domical part, are shown by a common ichnographical projection, while the skylight is exhibited in a kind of false perspective, and being without any connection with the kirb on which it is placed, it has the appearance of being raised upon its edge, resting upon two points in the kirb.

Figure 7, "is an ogee roof, whose plan is a pentagon, and shows the method of drawing the polygon figure to any given side; make a radius of that side, and draw the arches 2, 6; divide one of these arches into six parts, and turn them to the centre line, as shown by the letters and figures 5 *d*, 4 *e*, &c.; the centre *c* will draw a circle to receive the side 5 times,

6 is the centre to receive the side 6 times, *d* seven times, and so on to *i*, which is the centre to draw the circle to receive the side twelve times."

This problem should have been classed in practical geometry, as it has no reference whatever to carpentry. It is only true in the hexagon and dodecagon, and is very incorrect for the description of polygons upon a given straight line, which have fewer sides than six. In his diagram, he shows the method of describing the hip from the common rib being given; but the text contains no description of it.

Figure 8, "is a dome, whose plan is a hexagon, and shows how to divide a circle into any number of parts: divide one-fourth of the circle into the number of parts you would have the circle, as, 1, 2, 3, 4, 5, 6, and always take four of them. To find the backing of the curve-line hips, lay down the plan of the hip at the angle, as *a;* then take the distance 1, 2, at bottom, tack in a nail, then shift the hip-mould, and marking by it, as 1 2, 3 4, 5 6, 7 8, 9, 10, will show the wood to come off." In this description, Mr. Pain proposes to find the division of a circle into any number of parts; but as he does not mention any fixed ratio of these parts, they may be taken at pleasure, without rule; but allowing that he had neglected to name this condition, under which the circle was to be divided, and suppose that he meant the parts to be equal, and to be found by a general method; there is no regular rule of performing this problem but by an approximation. If we allow that the quadrant can be divided into equal parts, we must also allow that the whole circle will contain four times that number of parts; but the division of the quadrant into equal parts is equally impossible with that of the whole circle; the rule is therefore absurd, and consequently it is only accomplishing one absurdity by another, and wasting the reader's time to no purpose. In this problem, as in the last, he has also neglected to inform his reader how the hip is found, though it is sufficiently clear on the plate to present the idea of forming it to any intelligent person.

Figure 9, "is a dome on a circular plan; *a* and *b* show the section of the horizontal rib."

Figure 10, "is a dome on an elliptic plan; the centres for the mould of the horizontal ribs *d d*, are *a a*, *b b*, *c c*, *d d*; the place of that rib on the plan is found by dropping dot lines from the sections *d d: c c* on the top, is designed for a skylight." These descriptions are unintelligible.

Plate XIII. *Figure* 1, "shows the method for cutting the boards to cover the dome; divide the dome into as many parts as you think it will take boards, and draw lines to cut the edges of each board, and where they meet the centre line, that is the centre for the edge of each board. This is drawn one inch to a foot." This has already been shown and described by Swan, but he is deficient in not representing the boards as Pain has done; the description of the former, however, though short, is much clearer than that of the latter.

Figure 2, is taken from the *Practical House Carpenter*, but the description is to be found neither in the text nor on the plate. It must therefore be left to the sagacity of the reader to find it out. We suppose the diagram to represent the method of covering a dome by bending the boards with the joints on vertical planes passing through the axis. This method has already been shown by several of the preceding authors, of whom Price and Langley are the most accurate, and differ most as to the mode of ascertaining the form of the board, but come to the same result at last.

Oakley, Hoppus, and Price, perform the operation by straight ordinates, whereas Langley and Pain do it by curved ordinates: one method ascertains the form with as much accuracy as the other, but the operation with straight ordinates requires much less trouble than the other. Pain even shows many more lines than are sufficient, which superabundance makes his diagram much less intelligible to the understanding of his reader. The concentric arcs, which he has used as ordinates, are erroneous in principle, though the use of them does not affect the practice, as we shall here show.

Figure 3. "Let A B C be half the section of a dome passing through its vertical axis; divide the curve A B into as many equal parts as the number of boards of which the covering is to consist; through each point in the circumference draw a line to the centre C; and through each of the same points draw another line at right angles to the respective radii, and produce them upwards, as also the axis C B, so as to cut each of the tangents from the several points in the curve; then each of these tangents, so limited, are the radii of the successive ordinates; the tangent at the bottom is of infinite length, the next is limited, and the succeeding ones become gradually shorter and shorter, till the tangent and the arc become nearly of one length. So that the ordinates of the board exhibited in *Figure* 4, are arcs of radii, respectively equal to the tangents; consequently, the bottom ordinate of the board is a straight line, the next is the arc of a circle of a very flat curvature, the next is an arc of greater curvature, and so each arc becoming quicker and quicker in its curvature, till they reach the summit of the board, which is the last centre."

The most eligible method in practice, founded upon evident principles, is to suppose the dome to become an equilateral and equiangular polygon, and suppose the axal section A B C, *Figure* 5, perpendicular to one of the sides of the dome to be given, and the curve A B to be divided into equal parts, and suppose the parts to be extended upon B C produced; then, if lines be drawn through the divisions of the curve, and through the points of division in C B, produced perpendicular to the said B C; and if B D be drawn perpendicular to B C, equal to half the width of a board, and D C joined, and the ordinates produced so to meet D C; then, if the lines parallel to B D, contained within the triangle B D C be successively taken towards C, and applied on the perpendiculars from and on each side of C D produced; then if curves be drawn through the points at the extremities, they will terminate the edges of a board, which will accurately cover a side of the polygonal dome.

Let us now suppose the number of sides of this dome to be very great, then the sides will vary only in a very small degree, either from the inscribing or circumscribing sphere, and this variation will decrease as the number of sides is increased, and the excess or defect would become insensible; and if we suppose the sides to be infinite, the board which covers the side of the polygonal dome will accurately cover the inscribing or circumscribing spherical dome. This latter method is founded upon principle, but that of forming the bottom ends of the boards into curves is totally destitute of it.

Figure 6, from Pain's *British Palladio*, which he says, "is a pentagon to be covered with a domical roof. To find the curve of the boarding, divide the girth or curve of the rib on the back into as many parts as you please, as here into four, and draw them to the base-line of the rib *e a*, as 7, 8, 9; stretch out *a b*, the middle of the side, and 9 9, 8 8, 7 7, parallel thereto; then take one of the divisions on the girth of the rib, and set off from *e* to 7, 8, 9, *b*, and where that cuts the lines 7 7, 8 8, 9 9, *b*, there tack in nails, and bend a thin slip to the nails, and mark from *e* to *b*, as that curve directs; this will be one edge of the covering: prick these marks on the other side of the line *a b*, and proceed as before; then will the covering or boarding be complete. The covering or boarding of (*Figure* 7) is found in the same manner, which is very plain to inspection; the girth of" the

"rib being stretched out, and the parts set on as above directed."

When he says, "stretch out $a\ b$, the middle of the side, and 9 9, 8 8, 7 7, parallel thereto," he is not intelligible; however, if we understand that $a\ b$ is drawn at right angles to the side $e\ d$ of the polygon, and 9 9, 8 8, 7 7, drawn parallel thereto, the method which he uses will be found to be correct, and, we believe, original.

Figure 8, "shows the method for getting out the veneer, or cover for an elliptical dome or niche. Divide the circumference of one quarter of the plan into any number of parts, as here into 8, and draw them to the centre 4; let the first line from the transverse diameter be the edge of the veneer; the second line will be the middle of the next veneer; the third will be the other edge of it, and so on: continue this line out at pleasure: consider this line as a base, and draw thereon a section of the dome, as No. 1; then divide the circumference into four parts, draw them to the base-line at right angles, and transfer those distances to the corresponding line on the plan; then take the four parts on the girth, and run them on the line stretched out, 1, 2, 3, 4, this will be the length of the veneer; set the compasses on the plan, and strike a curve-line of this radius; then continue the middle line of the veneer, and where it intersects, that curve-line will be the point of veneer next the top of the dome; from this point set off the divisions 1, 2, 3, on the circumference by curve-lines; then take the width of the divisions 1, 2, 3, from the middle line of the plan, and set them on the same line stretched out to cut them at their respective distances, the points of intersection will be the breadth of that side of the veneer; connect them by a curve-line from the plan to the point, and you have one edge complete. For the veneer on the transverse diameter, this edge will serve as a mould; or you may set the half of the veneer to the other side of the plan, and draw a chord-line from these points; set this off that distance of the arch (the little curve) to be outside, and draw a line parallel to the chord-line, on which set off the breadth of the veneer on both sides, then with the whole length of the other veneer in the compasses, set one foot on that breadth, and strike a curve-line to cut the middle line on the transverse diameter; or repeat the curve from the other side, and where they cross will be the point of that veneer, from whence set off the divisions, and proceed as before. But as the radii of an oval are of different lengths, to get the other edge of the veneer, make a section as before, (see No. 2,) and set off, as before, the divisions on the base and plan, and strike the divisions on the girth, from the point of the veneer stretched out, intersect them from the plan, and those points connected will give the other side of that veneer, which will be a mould for the next adjoining; proceed again for every veneer by transferring that length from the plan, and the shortest length from the point; repeat the same operation for every veneer required.

Note. "The conjugate and transverse diameters will have the two sides of the veneer equal. Observe, only four parts are used, to prevent confusion in the figure; but the greater number of parts, the truer the line. Again, if your boards will suit, divide the plan to their number, and proceed as before for every board respectively."

This method is so absurd in every particular, that the coverings obtained are erroneous in the greatest degree; indeed, it leaves no room for argument, and we shall only observe, that in the true form of the boards, between the extremities of the greater and less axis, in any one of the four quarters, one side of the board would be concave and the other convex, where the dome has a considerable difference in its axis; and the greater this eccentricity or difference, the greater will be the degree of curvature of the concavity and convexity of the sides of these boards.

Figure 9, No. 1, shows groins and arches, of different descriptions, from the *Practical House Carpenter*. Pain divides this figure into several others, and distinguishes them by letters of the alphabet. He only gives the following description on the plate: "K centering for groins. L is a half groin cutting under pitch, for a door or window. G a Welsh groin cutting under pitch. M is the method of tracing the ribs and hips for a groin ceiling." *Figure* 9, No. 2, "N is a mould to bend over the body range; K to get the lines to set the jack-ribs by." The reader who has not already acquired a competent knowledge of geometrical lines, will profit but little from this description. The showing of the jack-ribs upon the diagram is an improvement. Swan has shown them perspectively, but the geometrical method of representing them is more serviceable to the workman, as it shows the lengths of the ribs distinctly. He observes that "G is a Welsh groin cutting under pitch," but he does not show how the crooked line, which he has exhibited, is obtained; and even if he had shown it, the method of constructing the rib would still have been wanting. In the mould N, for groin-centering, in order to find the place, or curve-lines, on the boarding, for fixing the jack-ribs, he has given no description, either in the text or on the plate, except that he writes, "the arch line a stretched out," and "half the base-line b," upon the respective sides; and, consequently, we have no other instructions to inform us how the mould N is found, than by inspecting the figure itself, and tracing out the operation by the connection of the lines; and even then we are left in the dark as to its application. The moulds for groin-centering upon this principle, were first shown by Price, as well for finding the angles of the jack-ribs, as the form of the boarding.

Figure 10, from the *Practical House Carpenter*, "is a bevel roof; the sides are parallel on one part of the plan, the other bevels. To frame this roof in ledgement, the principal rafters must be framed to a level base; that is, the ends of the beams all of one height from the face of the plate; when you come to lay them the other way, to frame in the purlins, there must be winding sticks held to the bases of the rafters, which winding sticks must be all out of winding; and as the width of the building diminishes, the backs of the rafters will lie in winding, as they will when in their places; and mind that they are backed according to the bevel of the plan, for turning them up to tumble in the purlins; by this method the business may be well completed." Allowing that the heels of the rafters are cut to their proper bevels with the backs, the application of winding sticks to such short distances will never make the sides fall accurately into their proper winding. This is altogether a mechanical operation; but it would have been no difficult task to have shown an operation strictly geometrical.

The foregoing remarks will be found to contain a fair and impartial statement of the geometrical improvements and errors of the several writers on Carpentry, at least as far as they have come to our knowledge: we shall now, in conclusion, draw a general result from the whole of their theories, and endeavour to trace the progress of the art towards its present state of comparative perfection.

The method of bracketing hip-rafters, which is said to be the invention of a Mr. Pope, of London, was originally presented to the public by Godfrey Richards, who also first represented roof in ledgements, in order to ascertain the several lengths and angles which the rafters make with each other.

The use of the trammel in common cases; the description

of a curve through points, by bending a lath, or slip of wood; cove-bracketing, and the construction of ribs in groined ceilings, disposed in vertical planes, were first shown by Halfpenny. In the latter, however, he divides the bases into equal parts, in order to place the ordinates, which is inconvenient; for the equi-distance of the ordinates leaves a very large portion of the curves at each extremity, where they are quickest, to be traced only by the eye. This writer also first described the formation of spherical and spheroidal niches, upon semi-circular and semi-elliptic plans, with semi-circular and semi-elliptic faces, under the names of *semi-circular* and *elliptic niches.*

To Price we owe the mode of framing roofs in ledgement, with all the beams and rafters laid out on a plane; though it must be remembered that the general outline had been previously described by Godfrey Richards. The squaring of the purlin of a circular dome, and of a conic roof or sky-light; the backing of angle-brackets (and consequently of ribs in general) by shifting the mould of the rib; the ordinary construction of groin-centering, and moulds for drawing the diagonal lines at the feet of the jack-ribs; the covering of domes, by bending the boards from the base to the vertex; and the stretching out of the surfaces of coved ceilings, were also first described by this writer.

To the writings of Batty Langley we are indebted for the extension of the superficies of polygonal roofs with curvilinear rafters; and likewise the covering of the frustum of a semi-cone for a soffit in a straight wall, with the axis of the cone at right angles to the plane of the wall.

The principle of forming boards to cover a dome, with the joints running in horizontal planes, or on the surface of a cone with a vertical axis, was laid down by Swan.

That of extending the superficies of a semi-cylinder on a plane, for the soffit of an aperture in a circular wall, with the axis of the cylinder at right angles to the surface of such wall, so as to cover the surface of the cylinder contained between the two walls and each spring of the aperture, was first exhibited by Pain; as was likewise the principle of squaring purlins for an elliptic dome, though very imperfectly.

The sum total of the geometrical constructions by these writers, may be comprised as follows: the use of the trammel; drawing curved lines through points; ascertaining the lengths of rafters, and the backing of hips for both straight and curvilinear rafters; framing of roofs in ledgement, whether rectangular or bevel on the plan; squaring purlins for circular or elliptic domes and cones; the construction of curvilinear ribs for angle-brackets, polygonal roofs, and plaster groins; centerings of groins; forming a conic soffit in a straight wall, with the axis of the cone at right angles to its surface; forming a cylindric soffit in a circular wall, with an horizontal axis; and the covering of polygonal roofs or domes with boards, whose joints fall either in horizontal or vertical planes.

These inventions, however, are far from being laid down in the most happy manner. The text of these authors is frequently obscure, and their diagrams, which have little connection with it, are badly projected, and little calculated to inform: they have likewise so far neglected the requisite arrangement, that their subjects are thrown together in a promiscuous jumble, without either attention to the affinity of their principles, or their order of succession in practice.

Of the several works quoted, Price's alone can justly claim the title of a treatise on carpentry.

Langley is in general tolerably intelligent; he has treated on all that has been done by his predecessors, and has attempted many things of his own; but his labours have not been successful.

In the diagrams of Pain, we find some useful practical hints; but his errors are numerous, and his inventions few His text, also, is more unintelligible than that of any writer who preceded him in this art.

The inventions and discoveries of the writers quoted, may be reduced to the following: Sections of prisms at right angles to one side or plane of the prism; coverings of prismatic and conic surfaces, in the most simple cases; and the method of ascertaining the lengths and backings of hips. To these principles, the Author of the ARCHITECTURAL DICTIONARY has added those of the intersection of one plane with another, the latter resting on three lines perpendicular to the former; the geometrical construction of all cases in spherical trigonometry, by solid angles; sections of a prism, cone, or cuneoid, through any three given points; the section of a prism making a given angle with a given parallelogrammatic section of such prism, and passing through any given line on the said section; the section of a cone passing through any line on a given axal or vertical section, and making a given angle with that section; the section through any three given points on the surface of a body, of such property that all sections parallel to a certain plane will be similar figures, having the seats and heights of the points upon one of the similar planes, and another section of the body in a given position to that plan, cutting all the said similar sections; the sections of various other bodies, whose properties are defined; the formation of the edge of a thin pliable surface, which, when bent upon the surface of a prism, may coincide in its edge with a section passing through any three given points on the surface of the said prism; the formation of the edge of a surface, to fit a conic section, passing through any three given points on the surface of the cone, while such surface and that of the cone coincide; the formation of the edge of a thin pliable surface to fit the section of a body cut by any prismatic surface, while the pliable surface coincides with that of the section made by the prismatic surface; the properties of the body being such, that all sections parallel to a certain plane will be similar figures, given a section of the body parallel to one of these sections, and another cutting all the said similar sections in a given position, and the intersections of the given planes on each other.

These subjects include the finding of the sections of cylinders and cones, spheres and spheroids, and the coverings of these bodies, under the circumstances already stated. To these, the author has added the following inventions or discoveries, viz., the method of extending the surface of a cylinder or cylindroid, being the centre of an arched aperture in an oblique wall, terminated by the faces of the said wall; and the covering of the surface of a part of a semi-cone, being the centre of an aperture, with its axis oblique to the surface of the wall which terminates such covering. In ascending groins, he has likewise shown the centering for brickwork, and ribbing for plastering; the construction of polygonal and annular groins, both level and ascending in a spiral, whether for centering or ribbing; cylindro-cylindric arches, or what are commonly, but improperly, denominated Welsh arches; spherical niches, both for straight and circular walls, under any circumstances: the true methods of constructing pendentive or spandrel ceilings, either spherical or spheroidal; the bevels of purlins in all positions to the common rafters; the formation of boards for covering spherical domes, without laying down either plan or section of the dome, entirely within the boards themselves; the forming of the lower boards, without centres, in the covering of a dome, with the joints in horizontal planes; the formation of boards to cover a spheroidal dome, with the joints of the boards in vertical planes; the covering of an elliptic dome with one mould

only; the covering of a spheroidal dome with boards having their joints in parallel vertical planes; the construction of a dome with horizontal ribs, without taking the trouble to square them by horizontal and vertical faces; the method of cutting purlins and jack-rafters to fit the hips, without laying the roof in ledgement; principles for the equilibrium of polygonal roofs without ties, so that the rafters may obtain a given ratio among themselves, provided the abutments be sufficient; a principle for preventing rafters without intermediate ties, from having any lateral pressure;—these two latter inventions have been several years before the public, in the architectural plates of Rees's *Cyclopædia*. To these might be added various other principles of less importance, which it is not necessary to recapitulate in this place. In most of the subjects above alluded to, he has given more than one method of operation, and in some instances he has multiplied his examples to five or six different modes of practice. One or two of the inventions in the foregoing list, he acknowledges, are only his own by their new application, the principles being known prior to his time; but he has adapted them to subjects to which they were never before applied; and he conceives that it requires at least as much ingenuity, and is frequently attended with more utility, to be able to apply an old or well-known principle to an useful object, as to discover a principle destitute of practical application: he has, therefore, not scrupled to include them in the list of his discoveries. Nor has he, while thus claiming credit for himself, denied it to others; as may be seen in his remarks on Pain's lining of a cylindric soffit in a circular wall, the principle of which was previously laid down by Price, in his centerings of groins. The inventions which the author has thus appropriated to himself, are the following: the application of the principle of covering the surface of the frustum of a cone to a spheroidal dome, with the joints in vertical planes; the application of the principle of covering an oblong spheroidal dome by one mould only; and the application of the principle shown by Price, in his centering of groins, to a cylindric soffit for an aperture in a straight wall, with its axis oblique to the surface of such wall; which latter was likewise attempted by Pain, but without success.

The author has not been able fully to satisfy himself as to the extension of the surface for the head of an aperture, splaying in the sides and level on the crown, so that the aperture shall form a semi-circle on one side of the wall, and a semi-ellipsis on the other; or a semi-ellipsis on each side, but of different horizontal dimensions, though of the same height. He is, however, convinced, that though the form be not geometrically true, it is much more correct than anything attempted by Langley or Pain; and on it, he has accordingly founded the principle by which alone the nature of the solid itself can be understood. And though unsuccessful in his attempts to extend the surface exactly, he has had the satisfaction of laying down such lines as will apply to the surface of the solid with far greater accuracy and dispatch, than could be obtained by the mechanical operation of plumbing the lines from the plan; by applying the distances on the plan upon their respective level lines on the surface of the solid, all drawn from one vertical line resting on the point where the two sides of the splay come in contact. By this means the line of every wall may be found correctly on the surface, whether the wall be straight or curved, or whether the axis of the solid stand oblique or at right angles to its surface; which cannot be done by any other method hitherto attempted.

In conclusion, it may be observed, that writers on carpentry have frequently been unsuccessful, for want of grounding their schemes upon the simple principles of the bodies they wished to construct; by losing sight of which, they have fallen into puerile operations, and drawn erroneous inferences.

In the course of this work, we shall treat of the several branches of the building art, and each article of those branches, in a manner similar to this on Carpentry; and all inventions, as well useful as otherwise, with every unsuccessful attempt at geometrical construction, will be noticed under their respective heads.

It is now only necessary to observe, briefly, that as the arrangement and classification of the subjects, as well as the mode of conceiving and presenting them in the diagrams, are altogether different from those adopted by the writers who have preceded us in this department, so it is believed, that this method will display the art of carpentry in a novel point of view, and reduce it to that pure scientific form it has never hitherto acquired. But notwithstanding all that has been done, and the great advances made in the art since the publication of the various works we have been examining, it is evident that the subject is not exhausted, but is still susceptible of many improvements. Such improvements will doubtless be effected, in time, by the labours of abler men who will carry to perfection the science and practice of an art so important and so interesting as that of Carpentry.

CARPION, a Grecian architect, who wrote a treatise on the Temple of Minerva, in the citadel of Athens.

CARRIAGE of a Wooden Stair, the frame of timber-work which supports the steps.

The carriage of a flight of steps, supported on one side by a wall, generally consists of two pieces of timber, inclined to the pitch of the stair. These pieces are called *rough-strings*, or *carriages*.

When a geometrical stair consists of two alternate flights, with a half pace between, the carriage of the half pace consists of a beam parallel to the risers of the steps, and several joists framed into the beam, for the support of the boarding. The beam which sustains the joists, is called the *apron-piece*, and that which sustains the rough strings at the upper end is called a *pitching-piece*. The joists of the half pace are sometimes tenoned into the pitching-piece, and sometimes bridge over it; but the steps of both flights are supported by string-pieces, as before. The upper ends of the string-pieces at the landing, rest upon an horizontal piece of timber, denominated an *apron-piece*.

If the steps wind round a circular newel, the carriage of the circular part consists of uprights and bearers, the latter of which are wedged into the wall; though it will answer the purpose as well, to frame them into a string placed against the wall. The uprights and bearers are either framed with mortises and tenons, or are dovetailed together.

When the staircase is of the dog-leg kind, with winders and a close newel, the carriage is formed of bearers let into the wall, and fixed to the newel post. For more information, see Stair-Casing and Hand-Railing.

CARTELLI. *See* Cartouches.

CARTON, or Cartoon (a French term, signifying *thick paper*, or *pasteboard*), in painting, a design on strong paper, to be afterwards chalked through, and transferred on a newly-plastered wall, which is to be painted in fresco. The word is also used for a coloured design, that is to be wrought into mosaic or tapestry.

CARTOUCHES, or Cartoozes (French, from the Italian *Cartoccio*), a kind of blocks or modillions, used in the cornices of wainscoted apartments; differing from modillions in being confined to the interior, whereas modillions are applied both externally and internally.

Cartouches, are ornaments representing a scroll of paper, usually in the form of a tablet, with wavings, whereon is some inscription or device.

They are sometimes drawn on paper, as in the titles of maps, &c., and are sometimes made of stone, brick, plaster, wood, &c., for buildings.

Norden uses this term to signify the winged globe, usually placed over the middle aperture of Egyptian buildings.

CARVED WORK, all those mouldings, planes, or other surfaces which are cut into ornaments, representing, in relief or in recession, foliages, animals, utensils, historical events, &c.

Mouldings are generally carved with leaves, honeysuckles, lions' heads, beads, egg and tongue, egg and dart, guilloches, reeds, flutes, &c. Tori are carved with guilloches, reeds, and flutes. Astragals are carved with beads, of various forms, strung together.

Ovolos, with egg and tongue, and at the corners with honeysuckles, as in Grecian architecture; or with egg and dart, and sometimes with leaves, as in Roman architecture.

Sima-rectas, with honeysuckles, of various forms, connected with scrolls and lions' heads at certain intervals, as in Grecian architecture; or with leaves of various kinds, as in Roman architecture. Sima-inversas, with leaves, stalks, &c., enclosed in borders.

Facias and large surfaces, with foliage interwoven or winding, or with historical subjects from the heathen mythology, and sometimes with flutes, fillets, &c.

But of all carved work none is so beautiful as that left us by the Gothic architects. Of the styles comprised, under this denomination, carving is one principal feature, and it is surprising to what perfection the art arrived; during this period of the dark ages, as they are called, it advanced gradually, and passed through many stages ere it arrived at its full maturity, from the simple and somewhat barbaric mouldings of the Normans, to the luxuriant foliage of the Decorated, or the elaborate richness of the Florid styles; and yet even the carving of the earlier periods is by no means to be despised; the specimens belonging to the Early English style, although somewhat stiff and harsh, possessed a simplicity and chasteness which was never afterwards surpassed. The Decorated style lays claim to the highest rank in carved enrichment, it approaches nearest to nature; indeed, it is almost nature herself, only changed in substance; everything connected with this period is full of grace and elegance. In the next, or Perpendicular style, the flowing lines of the preceding period were deserted for the straight; or if curved lines were introduced, they were of a character purely geometrical; the method adopted was rather artificial than natural, and we see but few examples of foliage such as is found in the previous styles; there was, however, an elaborateness and exuberance at this period never before attempted; in some instances, to such an extent was carved enrichment employed, that scarcely any portion of the plane surface was discernible. This is very conspicuous in the fan-work, as it is termed, which was introduced into the vaulted roofs; we would especially cite, as an example, the roof of Henry the Seventh's Chapel, Westminster, than which, we suppose, there exists not a more elaborate specimen of carving, at least in a work of such magnitude. The light and beautiful pendents of this chapel afford a magnificent specimen of the most enriched and delicate sculpture. Other examples of the same kind, are St. George's Chapel, Windsor, and the Chapel of King's College, Cambridge. Equally beautiful specimens of carving, sometimes even of a more minute description, may be seen in works of a smaller kind, such as fonts, altar-screens, &c., more especially in the latter, in some of which the elaboration is carried to so great an extent, that nothing less than a close and diligent inspection will suffice to unfold its beauties.

CARVEL-BUILT, in ship-building, when the edges of the planks join each other, the vessel is said to be *carvel built.* This term is used in contradistinction to *clinker-built*, which is when the edges of the planks are lapped upon each other.

CARVER, an artist employed in the carving of wood.

CARVING, in general, is the art of cutting a body by recession, in order to form upon it various fanciful representations, as foliages, flowers, fruit, animals, landscapes, or historical events, either in relief, or recessed within a general surface. In this sense, carving comprehends both statuary and engraving, the latter upon either wood, stone, metal, or any other material.

In a more particular sense, carving is the art of cutting wood, as in the above definition. *See* Carved Work.

CARYATIC, whatever relates to the ancient country of the Carians.

Caryatic Order, an order of architecture, whose entablature is supported by female figures instead of columns: the figures themselves are called *Caryatidæ*, *Caryales*, or *Carians*.

The Caryatic order differs from the Persian in having the entablature supported by females, whereas in the latter it is supported by males. *See* Persian Order.

The history of these orders, as related by Vitruvius, is as follows:

"Caria, a city of Peloponnesus, having joined with the Persians against the Grecian states, and the Greeks having put an end to the war by a glorious victory, with one consent declared war against the Caryatides. They took the city, destroyed it, slew the men, and led the matrons into captivity, not permitting them to wear the habits and ornaments of their sex: they were not only led in triumph, but were loaded with scorn, and kept in continual servitude, thus suffering for the crimes of their city. The architects, therefore, of those days, introduced their effigies sustaining weights, in the public buildings, that the remembrance of the crime of the Caryatides might be transmitted to posterity. The Lacedæmonians, likewise, under the command of Pausanias, the son of Cleombrotus, having, at the battle of Platea, with a small number, vanquished a numerous army of Persians, solemnized the triumph, by erecting, with the spoils and plunder, the Persian portico, as a trophy, by which to transmit to posterity the remembrance of the valour and honour of the citizens; introducing therein the statues of the captives, adorned with habits in the barbarian manner, supporting the roof."

Whether this account is correct, in any respect, seems doubtful; it is certainly incorrect as far as it relates to the origin of the order, but whether its distinguishing appellation is rightly attributed to the above circumstances, remains a matter for consideration; we think the evidence is decidedly against Vitruvius. In the first place, be it remembered, there is no allusion made to such circumstances by the Greek historians; and in an inscription brought from Athens by Dr. Chandler, containing a description of the temple of Pandrosus, the figures are called κοραι, or damsels, and are thence naturally supposed to represent the maidens engaged in the celebration of the Panathenaic festival. Mr. Gwilt, who was the first to remark upon the incorrectness of the account of Vitruvius, is of opinion, that the figures were named after the goddess Diana, to whom the title Caryatis was given by the Lacedæmonians, from the circumstance of her having made known to them the story of Carya, daughter of Dion, king of Laconia, who was turned into a nut-tree by Bacchus.

With respect to the epithet, Caryatis, we are inclined to think rather that the goddess obtained this surname from being worshipped especially at Carya, near Sparta, where she had a temple, and where also the Lacedæmonian virgins celebrated an annual festival in honour of her; but as regards the main point in question, we think there can be little doubt but that, as is evidenced by an old commentator on Statius, the term Caryatides was applied to the virgins employed in the service of Diana, and that female figures were first employed in the architecture of the Greek temples as representations of the virgins engaged about the service of the deity to whom the temples were dedicated.

That the figures of men and animals were used for the purpose of supports in the place of columns, long before they were so employed by the Greeks, is well known. That they were not uncommon in Egypt, we learn from Diodorus Siculus, who informs us, that the roof of the hall in the sepulchre of King Osymandyas, was supported by animals instead of pillars, each composed of a single stone, and twenty-four feet in height. Psammeticus also employed colossal statues twelve cubits in height in the propylæum which he erected on the east side of the temple at Memphis.

In Denon's *Travels in Egypt*, we find, among other fragments, representations of five insulated pilasters or pillars, bearing an entablature; the fronts of which are decorated with priests or divinities.

We find several instances of a similar application of men and animals, in one case of elephants, in the temples of India, as in the temple of Elephanta, that near Vellore, and several others.

The molten sea, spoken of in Holy Writ, was supported by twelve bulls; and in the *Odyssey* of Homer, book vii. verse 118, we find the effigies of animals, both rational and irrational, employed as decorations. We do not learn, however, that these latter representations were employed as columns to support an entablature; and there is reason to believe that they were nothing more than ornamental sculptures. In Stewart's *Antiquities of Athens*, we find a most beautiful specimen of Caryatic figures supporting an entablature, consisting of an architrave cornice of a very elegant profile.

The examples to be found amongst the Greeks are those in the temple of Pandrosus, and five specimens out of six previously existing, supporting an entablature adjacent to the temple of Erectheus. In this case there is no frieze, but the entablature is carried to an extraordinary height.

Various fragments of male figures are also met with among the Roman antiquities, which, from their attitudes and ornaments, appear to have supported the entablatures of buildings.

Besides Caryatides and Persians, it is sometimes customary to support the entablatures with figures, of which the upper part represents the head and breast of the human body, and the lower part an inverted frustrum of a square pyramid, with the feet sometimes projecting out below, as if the body had been partly cased: figures of this form are called *Termini;* and had their origin in stones used by the ancients for marking out the limits of property belonging to individuals. Numa Pompilius, in order to render these boundaries sacred, converted the Terminus into a deity, and built a temple, dedicated to him, on the Tarpeian Mount, wherein he was represented by a stone, which in the course of time was sculptured into the form of a human head and shoulders, with the lower parts as we have just described. On particular occasions, this idol was adorned with garlands.

Persian figures are generally charged with a Doric entablature; the Caryatides, with an Ionic or Corinthian architrave cornice; and the Termini, with an entablature of any of the three Grecian orders, according as they were themselves decorated.

Male figures may be introduced with propriety, in arsenals, or galleries of armour, in guard-rooms, and other places devoted to military affairs; they may either represent the figures of captives, or of martial virtues; such as Strength Valour, Wisdom, Prudence, Fortitude, &c.

As these figures should be of a striking character, they may be of any colossal size that will agree with the architecture of other parts of the building.

In composing Caryatides, the most graceful attitudes and pleasant features should be chosen; and, to prevent an appearance of stiffness, the drapery and features should be varied in the different figures of the range; at the same time, a general uniformity of shape should be preserved throughout. They should always be of a moderate size, or they will appear monstrous, and destroy those sensations, which representations of the fair sex ought to inspire.

Le Clerc says they may be advantageously employed for sustaining the canopy of a throne: in which case, they should be represented under the figures and symbols of heroic virtues. In banqueting-rooms, ball-rooms, or other apartments of recreation, they must bear such characteristics as are calculated to inspire mirth and promote festivity.

As Termini are susceptible of a variety of decorations, they may be employed as embellishments for gardens and fields; where they may represent Jupiter, the protector of boundaries; or some of the rural deities, as Pan, Flora, Pomona, Vertumnus, Ceres, Priapus, Faunus, Sylvanus, Nymphs, and Satyrs. They are also much employed in chimney-pieces and other interior compositions.

CASE (from the French, *caisse,*) an outside covering, envelope, box, or sheath; applied generally to such coverings as completely surround the object enclosed. In building, it means the shell or carcase of a house.

Case-Bays, in naked flooring, the joists framed between a pair of girders. Flooring-joists framed with one of their ends let into a girder, and their other ends inserted in the wall, are called *tail-bays.* The case-bays of floors and roofs should not exceed ten feet.

Case of a Door, a wooden frame, in which the door is hung; door-cases are either constructed of architraves and linings, or wrought framed, rebated, and beaded; in the latter case they are called door-frames.

Case of a Stair, a name given to a wall by which a staircase is surrounded.

CASED, a term in masonry, indicating that the outside of a building is covered or faced with materials of better quality than those of the backing or inside of the walls. Thus brick walls are frequently cased with stone, or with the best kind of bricks. *See* Wall.

Cased Sash-Frames, have their vertical sides hollow, to conceal the weights for hanging the sashes. *See* Sash-Frame.

CASEMATE, a cove, or hollow cylindrical moulding, the section of which is from one-sixth to one-fourth part of a circle.

CASEMENTS, sashes or glass frames, opening on hinges, and revolving upon one of their vertical edges. When a casement fills the whole aperture, it is called *a single casement;* and when two are used, they are called *double casements, folding casements,* or *French sashes.*

Casements are more liable to admit rain, wind, or snow, in stormy weather, than vertical sliding sashes, particularly at the bottom, when they open from the inside.

CASING of Timber-Work is when the outside of a timber building is plastered all over with mortar; after which it is made to resemble stone-work, by striking it, while wet.

with the edge of a trowel, or other implement, guided by a rule. This operation is best performed on heart laths, because the mortar is apt to cause a rapid decay in sap laths. The coating is commonly laid in two thicknesses, the second being applied before the first is dry.

CAST (from the Danish, *kaster*, to throw), in plastering, a piece of insulated plaster, originally formed in a cavity, the bottom of which is the reverse of the face of the cast.

The operation is thus performed: a small quantity of plaster of Paris is mixed with water in a bason, or pan, and stirred up with a spatula, till thoroughly incorporated; more plaster is then added by degrees, till the mixture assumes a moderate consistency, such as to flow on all sides when poured on a horizontal surface; the mould being slightly oiled or greased, to prevent adhesion, the liquid plaster is poured in, so as to fill the mould, or something more. When stiffened in a small degree, the superfluous parts are scraped off to the middle, or in several parts at the edges; when it begins to heat, which happens in a few minutes, it will be sufficiently hard: then, if the mould be made of wax, it may be removed by bending it away from the cast, gently at the edges, quite round, using the parts left on the surface as handles; and proceeding gradually towards the centre, till the cast is quite relieved; but if the material of the mould be brimstone, a slight knock on the back will relieve it. As this operation can only be performed in the direction of a straight line, no part of the cast near the bottom of the mould must project from this line to a greater distance than any part more remote, otherwise it cannot be drawn out without breaking such projections. If more relief is required, than what can be given by the mould, the cast must be undercut with a knife.

If the impression can be relieved of the mould, the cast may be of one piece; otherwise it must be made in several segments, and in such manner as may best conceal the joinings.

Plaster casts are sometimes used for mouldings, instead of working them by hand, in situations where they cannot be conveniently run with a mould.

An exact representation of an original piece of sculpture, or even of a living animal, may be taken, whether generally concave or convex, by using the original as a mould; on which, having first oiled or greased the parts in a slight degree, pour the plaster, as just directed; and this impression is in its turn to be used as a mould, and will give a fac-simile of the original.

Pliny mentions the casting of faces from nature, as being early in practice among the Greeks.

This useful art supplies the painter and sculptor with exact representations from nature, whether of men, brute animals, draperies, or plants; it multiplies models of all kinds, and is now brought to such perfection, that casts of antique statues are made perfectly similar to their prototypes, except only with respect to colour and materials.

The introduction of plaster in architectural decorations, dates from the prevalence of the style called by us the Elizabethan, but its influence is more conspicuous during the succeeding or Italian style. It was first employed in carved and paneled wainscoting, and in the enrichment of the highly-decorated ceilings, which were a prominent feature in buildings of the period. At the first onset, however, the plaster was not cast, but each individual ornament moulded by hand, fixed in the situation which it was intended afterwards to occupy; it was indeed merely the substitution of plaster for wood, and the only advantage consisted in the facility with which the former could be carved, whereas the execution of the latter was difficult. This advantage was further extended at the commencement of the eighteenth century, by casting the plaster ornaments in moulds previously prepared for the purpose, so that from a single mould might be produced a number of casts, thus reducing the expense considerably. Soon afterwards another material was employed in similar decorations; this was the pulp of paper, which was very generally used, though not so extensively as plaster; through the poverty of the designs in this material, as well as the imperfection in the machinery of those days, it fell into disuse, and was at last entirely superseded by plaster. The latter material, however, could not produce the desired ultimatum, it answered very well so long as the Greek style of ornamentation prevailed; but when this was superseded by the French, Flemish, and Elizabethan, its defects were seriously felt: it was by no means calculated to express the fantastic forms of the latter, or the luxuriant richness of the former styles, especially when, as was frequently the case, the design was marked by bold projection and deep undercutting. This difficulty led to a new trial of the carton pierre, or papier maché as it is now called, which, by the aid of improved machinery, and a greater knowledge of chemical and general science, has been advanced to a high state of excellence, and is in every respect superior to plaster casts previously employed. One invaluable advantage it possesses, is, that it preserves the indents and undercutting of the original or mould, however much recessed; in fact, it can readily be made to assume any form, however intricate. Add to this its hardness and durability, its adaptation to external ornaments, for it is known to have remained uninjured for many years, though exposed to the vicissitudes of the weather; its indestructibility by vermin, its lightness, and its sharpness, and truth of outline, and its superiority to plaster, will not be for a moment questioned. In many of the above particulars, it is superior even to wood, to which it is in some respects similar, for it may be cut with a saw or chisel, bent by heat or steam, and even planed and smoothed with sand-paper. Further, its lightness will allow it to be fixed in any situation, without fear of displacement, and it requires but nails or screws, and even in some cases only needle-points, to secure it firmly in its position. It holds pre-eminence over plaster, in as much as it will receive colour very readily, and gilding much more so than the generality of materials to which such enrichment is applied.

Another article which has of late been introduced as a substitute for the above materials, is embossed leather, which in some instances is superior to either of them. It can be made to assume any degree of relief short of the complete round, and it preserves all the sharpness and fineness of outline possessed by the mould from which it is cast. The moulds in this process are of metal, into which the leather previously prepared by steaming, is forced by a combination of hydraulic and pneumatic pressure, by which extraordinary power the finest lines on the mould are repeated with the greatest accuracy on the copy. It might be supposed from the nature of the material, that this delicacy of outline would be deteriorated by time, or that the cast might be altogether destroyed by damp; but there is really no ground for apprehensions of this nature, as the casts are found under all circumstances to preserve, undiminished in the minutest details, the form transferred to them from the original mould, and to be improved and hardened rather than injured by age. This material has an advantage in the facility with which it can be made to imitate old carved work; indeed, when introduced in the restoration of such works, it is difficult to distinguish the original from the imitation; it may be coloured or gilded as desired. It is applicable to all kinds of interior decorations, such as cornices, friezes, &c., and has been employed even in the entire paneling of rooms.

Another material which, until very recently, was entirely unknown to us, but which, since its first introduction, has come into extensive use, threatens to prove a formidable rival to the above-mentioned articles—we allude to Gutta Percha. This substance has not been tested sufficiently to allow us to speak decidedly as to its applicability to the purposes we are considering; it is moulded into cornices, panels, and other forms of architectural decoration, and is on many accounts eligible for such uses; it can be moulded, cast, stamped, or embossed, into any form however elaborate, and is susceptible of colour; it has, however, disadvantages which for the present must preclude its employment; for, although it promises considerable hardness, it is readily injured by contact with any sharp body; besides this, it is liable to soften and liquify when exposed to an elevated temperature. This last defect has been modified by a process to which the material is subjected in its manufacture, which is termed metallo-thionising, but still it has not been entirely removed. The properties of this production, however, have not yet been sufficiently developed to decide upon its capabilities; many improvements will doubtless be introduced into its manufacture, as its nature becomes more fully understood.

Cast, among plumbers, a little brazen funnel at one end of a mould, for casting pipes without soldering, through which the melted metal is poured into the mould.

Cast, *Rough.* *See* Rough Cast.

CASTELLA, or Castles, in British antiquity, one of the three kinds of fortifications built along the line of the wall of Severus, the other two sorts being denominated *stations* and *towers.* The Castella were neither so large nor strong as the stations, but much more numerous, there being in this wall no fewer than 81. The figure of the castellum was cubical, 66 feet in each dimension, fortified on every side by thick and lofty walls, but without any ditch, except on the north side, where also the wall was raised much above its general height, and with the adjoining ditch formed the fortification.

The castella were placed in the intervals between the stations, generally at the distance of about seven furlongs from each other, and guards were constantly kept in them, consisting of a certain number of men, detached from the nearest stations. *See* Castle.

Castella, in Roman antiquity, also denoted the reservoirs, in which the waters from the aqueducts were collected, whence the city was supplied by leaden pipes.

CASTELLATED HOUSES, those mansions which succeeded the castles and fortified residences of the feudal barons; they still preserved the appearance of strength, although in reality incapable of defence against a regular force. These buildings were provided with battlements and turrets, rather for ornament, however, than for practical purposes.

The windows are generally closed horizontally with labels, over them; the apertures are sometimes divided by mullions, consisting of one or more munnions in the breadth, and one or two transoms in the height, by which the great opening is divided into several smaller apertures, sometimes arched under the lintels, and sometimes also under the transoms. One of the most remarkable of these edifices is Haddon-Hall, Derbyshire.

CASTING, the act of taking the impression of any surface, whether plain or sculptured, by pouring a liquid matter on that surface. *See* Cast.

Casting, in joinery and carpentry, is said of a piece of timber, when its sides are bent or twisted from their original surfaces, by the fibres being unequally heated, dried, or moistened; or by being naturally disposed in different directions; or the twist may, perhaps, arise from different degrees of hardness in the body, occasioned by knots, &c. This effect is otherwise called *warping.*

Casting of Brick or Stone Walls. *See* Rough Cast.

Casting of Bronzes, is thus performed: The figure to be cast from must have a mould made on it, consisting of a mixture of plaster-of-paris and brick-dust, in the proportion of not more than one-third of the former, to two-thirds of the latter. The thickness of this mould must be according to its length and breadth, in order to be sufficiently strong. Little channels, tending upwards, should be cut in various parts of the joints, to give vent to the air forced out by the metal as it runs into the mould. After the mould is made, a thin layer of clay is spread smoothly and uniformly over its inner surface, of the intended thickness of the bronze; the mould is then closed, and its cavity filled with a composition of two-thirds brick-dust and one-third plaster, mixed with water, to form the core; previous to which, should the work be of any magnitude, it will be necessary to insert strong irons bars within the mould, to secure it from accidents, and to facilitate the removal of the core. The mould being then opened, and the clay removed, is with the core thoroughly dried; to effect which more perfectly, they are exposed to the action of a charcoal fire or lighted straw; great attention is required to this part of the process, for should the least moisture be suffered to remain, the mould will burst, and the cast be blown to pieces, to the great danger of the lives or limbs of the workmen. When the mould is finally closed, the cord must be supported in its place by short bars of bronze, running from the mould into the core. The whole then is bound round with iron bars, proportioned in strength to the weight of the cast, and laid in a proper situation for receiving the metal, supported by dry materials, as sand-stones, &c., to prevents accidents. In placing the mould, due care must be taken to connect its mouth with the reservoirs, by means of a channel on an inclined plane, that the liquid metal may run freely. The form of the furnace, and mode of running, are similar to those practised in bell-founding.

Casting of Lead. *See* Plumbing.

CASTLE (from the Latin, *castellum,* a diminutive of *castrum*), in ancient writers, a town or village surrounded with a ditch, and wall furnished with towers at intervals, and guarded by a body of troops.

Castellum originally seems to have signified a smaller fort, for a little garrison. Though Suetonius uses the word where the fortification was large enough to contain a cohort.

According to Vegetius, the *castella* were often, like towns, built on the borders of the empire, where there were constant guards, and fences against the enemy.

Horsley takes them for much the same with what were otherwise denominated *stations.* *See* Castella.

Castle, in a modern sense, is a place fortified either by nature or by art, in a city or country, to keep the people in their duty, or to resist an enemy. In the more extensive interpretation of the word, it includes the various methods of encampment, but in its stricter meaning, it is usually applied to buildings walled with stone, and intended for residence as well as for defence. Few branches of historical research have been so little attended to, as that which relates to military architecture. Castles, indeed, such as we now see them, were of late introduction to the world. Whether we may rank them with the accommodations of life brought by the crusaders from the East, is doubtful: but this much seems tolerably certain, that it was in France, England, Germany, Switzerland, and Savoy, that the system of castellation first prevailed. In Italy, till the Normans got possession of Naples and Sicily, castles were comparatively few. We may at least date their general adoption in Europe with the feudal system.

The early British fortifications seem to have been little more than mere entrenchments of earth. Cæsar, however, penetrated not far enough to know the true nature of the British fortresses; and in his work, *De Bello Gallico* (lib. v. section 17), has given only the description of a lowland camp. In all parts of England, there is a vast number of strong entrenchments of a very peculiar kind, situated chiefly on the tops of natural hills, and which can be attributed to none of the different people who have ever dwelt in the adjacent country, but the ancient Britons. That they may have been used at different times, and occupied upon emergencies, by the subsequent inhabitants of the island, is no more than probable; but there are many, and undoubted reasons, for deeming them the strong posts and fastnesses of the aboriginal settlers, where they lodged their wives, formed their garrisons, and made their stand. That the Britons were accustomed to fortify such places, we have the authority of Tacitus, who, describing the strongholds formed and resorted to by Caractacus, says, "*Tunc montibus arduis, et si qua clementer accedi poterant, in modum valli saxa præstruit.*"—Annal. lib. xii. sect. 33. One of these entrenchments still makes a formidable appearance on a mountain hanging over the vale of Nannerch, in Flintshire, called Moel-Arthur. But their situation being so high that they could have no supply of water except from the clouds, they were often liable to be untenable for a considerable time together.

One of the most important of these fastnesses in our own country, is the Herefordshire Beacon, situated on a spot that could not but be an object of the utmost attention to the original inhabitants of those territories, which afterwards were deemed distinctly England and Wales, from the very division here formed. It is on the summit of one of the highest of the Malvern hills, and is known by the name just mentioned. It has been by turns attributed to the Romans, the Saxons, and the Danes, but its construction as a stronghold shows it was designed as a security for the whole adjacent country on any emergency. Another of these fortresses is at Bruff, in Staffordshire, which has been described by Mr. Pennant, in his *Journey from Chester*, p. 47, and exactly answers the account of Tacitus. It is placed on the summit of a hill, surrounded by two deep ditches, and has a rampart formed of stone. Other instances are adduced by Mr. Pennant, in his *Tour in Wales*, and by Mr. King, in the first volume of the *Munimenta Antiqua:* but a stronger instance than all, perhaps, is given by Mr. Gough, in the *Additions to Camden*, vol. ii. p. 404, where he shows that the true Caer Caradoc, the very fortress alluded to in the sentence we have quoted, which, if not the royal seat of Caractacus, seems to have been at least his stronghold, was in Shropshire, two miles south of Clun, and three from Coxal, being a large camp, three times as long as it is broad, on the point of a hill, accessible only one way, and defended on the north side by very deep double ditches, in the solid rock; whilst on the east, the steepness of the ground renders it impregnable. On the south it has only one ditch, for the same reason: and the principal entrance is on the west side, fenced with double works; whilst to the south-west it is even fenced with triple works. The most extraordinary, however, of all these kinds of fortresses, is situated in Caernarvonshire, called *Tre'r Caeri*, or *The Town of Fortresses.* The plan and elevation of this ancient stronghold and abode is given by Mr. Pennant, in his *Tour in Wales*, vol. ii. p. 206. On the accessible side it was defended by three rude walls of stone; the upper ones being lofty, about fifteen feet high, and sixteen broad; exhibiting a grand and extensive front. The space on the top is an irregular area; but the whole is filled with cells, some round, and some oval, and some also oblong or square. Several of the round ones were fifteen feet in diameter; which brings to mind the houses of the ancient Gauls, described by Strabo; and of those that were oblong, there was at least one even thirty feet in length. Of the same kind of fortresses were Penmaen Mawr, in Caernarvonshire; Warton Cragg, in Lancashire; Old Oswestry, in Shropshire; the irregular encampment of Maiden Castle, near Dorchester: and probably Old Sarum, whose character was new-modelled by the Romans. Mr. King, in the *Munimenta Antiqua*, vol. i. p. 63, considers the dens in the mountains and the thickets, of Scripture, as strongholds or hill-fortresses of the kind described. When Samson had made a great slaughter of the Philistines, we are told he went and dwelt in the top of the rock Elam; where we find, afterwards, three thousand men of Judah went up to confer with him. That hill-fortresses were used in the earliest ages, there can be little doubt. The Israelites, when their land was invaded by Jabin, the king of Canaan, in consequence of an exhortation from Deborah the prophetess, assembled to make their stand upon Mount Tabor. Among the Indians of South America, strongholds, of a similar nature to those of Britain, have been frequently discovered. Ulloa's *Voyage to South America*, vol. i. p. 503–504. And a very curious instance of the attack and surrender of one in Sogdiana, in Asia, in the time of Alexander the Great, is related by Quintus Curtius, lib. vii. chap. xi. The anecdote is worth the reference of the reader.

The British mode of warfare appears to have received but little alteration from the introduction of Roman tactics. Till finally subdued, their princes showed abilities both in the command of armies and in the conduct of war; they chose their ground judiciously; formed able plans of active operations; and availed themselves of all the advantages of local knowledge: but to the fortresses described, if we may rely on the testimonies of our ancient writers, they did not very frequently retire. Their deficiencies both in the attack, the construction, and the defence of such places, must have been very obvious even to themselves; and as they delighted to live, so they usually chose to fight, in open plains. Their impatient courage, and their aversion from labour, made them unable to endure the delays and fatigues of defending or besieging the castles of their time; and they often reproached the Romans with cowardice, for raising such solid works about their camps and stations. See Boadicea's famous speech to her army, in *Xiphilin, ex Dione in Nerone.*

Of the Roman military works in this country, they were for the greater part temporary; many, however, were stationary posts; and some few, to the retention of which the greatest importance was attached, became walled *castra.*

Cæsar, in the work already quoted, *De Bell. Gall.* lib. vii. describes one of his camps as fortified very much in the manner of a walled city. A few of the Roman stations in our own country assist in throwing light on the description; and, in short, such as were so surrounded, appear to have been the link of connection between the British earth-work and the feudal castle.

Richborough, Portchester, and Pevensey, are the three greatest fortresses the Romans have left us. Richborough, the very earliest in order of time, is supposed to have been begun in the year 43, in the reign of Claudius; but not to have been completed till 205, under the direction of emperor Severus. There are in this distinguished fortress, says Mr. King, (*Munimenta Antiqua*, vol. ii. p. 8) still plainly to be traced all the principal parts of one of the very greatest and most perfect of the stationary camps. The upper division for the general and chief officers, and the lower division for the legion. In the former, the prætorium with its parade,

and the sacellum, or small temple, for depositing the ensigns. In the walls too are the traces of the four great gates; the decuman, the prætorian, and the two posterns. The great courses of stone, with which the wall is formed, are separated from each other by alternate layers, composed entirely of a double course of bricks each; as in the walls of Verulam, Silchester, and other of our Roman towns.

The Roman remains at Portchester are not perhaps so clearly to be traced; since, having been constantly used as a fortress in succeeding ages, it has received vast and extremely various additions: and presents us with specimens of military architecture in almost every period, from the Normans to the time of Queen Elizabeth.

Similar alterations to those first mentioned, have given so strong a turn to the general character of Pevensey, that its real æra has been sometimes doubted; though portions of the Roman wall, as well as the decuman gate, may be easily and accurately traced.

Here too it may not be irrelevant to observe, that the castle at Colchester, in Essex, has been sometimes taken for a Roman fortress. And this not only because it has many of the same sort of tiles which are found in Roman walls, but because they are laid in the same manner, with bands. Though, if the building be examined with attention, there may be traced, in almost every part, evident marks either of the later Saxon or Norman workmanship: and though many of the tiles which are used in it may have been gathered from the remains of Roman buildings, the greater part appears to have been made on purpose. *See the Archæologia*, vol. iv. p 33.

That in the Roman times, however, there must have been many other such walled stations as those at Richborough, Portchester, and Pevensey, there can be little doubt. The Saxons, in the course of their long wars with the Britons, may be fairly supposed to have destroyed many of the fortifications which had been thus erected: and after their final settlement, they neglected to repair those which remained, or to build many of their own. By these means the country became open and defenceless; which greatly facilitated the incursions of the Danes, who met with little obstruction from fortified places. That there was, however, something like a castle at Bamborough, in Northumberland, we have the concurrent testimony of historians, as Matthew of Westminster, p. 193, sub ann. 547. *Saxon Chronicle*, p. 19. Roger Hoved. p. 238, b. Bede, lib. iii. chap. vi. p. 12: a castle at Corfe, in Dorsetshire, is said to have existed in the days of Edgar. Gough's *Add. to Camden*, vol. i. p. 49. King's *Munimenta Antiqua*, vol. iii. p. 209. Portchester castle, during this period, probably retained its designation. And Mr. King, *Munimenta Antiqua*, vol. iii. p. 211, has taken considerable pains to prove that the fortress at Castleton, in Derbyshire, is of as high antiquity.

Alfred the Great, however, seems to have been the first of our princes with whom the building of castles became an object of national policy. Though, if Asser's authority may be received, they were not exactly what the reader, at the first mention of their name, might take them for; since they were composed not only of stone, but of wood; Asser *de Reb. gestis Alfredi*, p. 17, 18. Elfleda, too, his daughter, governess of Mercia, who seems to have been the only person in the kingdom who properly complied with the commands, and imitated the example, of her illustrious father, and who inherited more of the wisdom and spirit of Alfred than any of his children, not only followed his steps by fighting many battles with the Danes, but built not less than eight castles in the space of three years, to check their incursions. Hen. Hunt. *Hist.* p. 204. A still more remarkable instance of the knowledge of castle-building at a short period subsequent to this, may be found in William of Malmesbury, chap. vi. when he mentions the rebuilding of Exeter by Athelstan, who died in 941. "*Urbem igitur illam*," says the historian, "*quam contaminatæ gentis repurgio defæcaverat*, turribus munivit, *muro ex quadratis lapidibus cinxit*." And from the few remains of the fortifications of this period, we find, that the walls precisely answer Malmesbury's description. They were faced with these four-square stones both within and without, and the intermediate space between the facings was filled up with rubble or rough flint-stones, mixed together with a strong and permanent cement. It is to this period too, that the most judicious of our writers have referred the castle at Colchester, which has been already mentioned. Its form is four-square, flanked at the four corners with strong towers, and it is about two hundred and twenty-four yards in circumference on the outside, all projections and windings included; the four sides nearly facing the four cardinal points. Some have even gone so far as to call this venerable ruin British; others, as we have already said, have attributed it, with a greater share of plausibility, to the Romans; but Camden and our better writers ascribe it to Edward the Elder, who repaired the walls and rebuilt the town, in the beginning of the 10th century.

Still, however, the paucity of strong posts in the island during every period of the Anglo-Saxon history, may be constantly observed. And it is more than probable that to this defect we may attribute the defeat of Harold; since it became necessary that all should be risked upon the issue of a single battle. The Conqueror, himself, was evidently sensible that the want of fortified places in England had greatly facilitated his conquest, and might, at any time, also facilitate his expulsion. He therefore made all possible haste to remedy the defect, by building magnificent and strong castles in all the towns within the royal demesnes. "William," says Matthew Paris, "excelled all his predecessors in building castles, and greatly harassed his subjects and vassals with these works." Matthew Paris, *Hist.* p. 8. col. 2. And his earls, barons, and even prelates, imitated his example; and it was the first care of every one who received a grant of an estate from the crown, to build a castle upon it for his defence and residence. The disputes about the succession, in the following reigns, kept up this spirit for building great and strong castles. William Rufus was still a greater builder than his father; and Henry I. was not idle in adding to their number. "William Rufus," says Henry Knyghton, col. 2373, "was much addicted to building royal castles and palaces, as the castles of Dover, Windsor, Norwich, Exeter, the palace of Westminster, and many others, testify; nor was there any king of England before him that erected so many, and such noble edifices." Though of one or two of these, William Rufus was only the improver. But the rage for building castles never prevailed so much in any period of the English history as in the turbulent reign of Stephen, between 1135 and 1154. In this reign, says the writer of the *Saxon Chronicle*, p. 238, every one, who was able, built a castle; so that the poor people were worn out with the toil of these buildings, and the whole kingdom was covered with castles. And this last expression will hardly appear too strong, when we are informed, that, besides all the castles before that time in England, no fewer than eleven hundred and fifteen were raised from the foundation, in the short space of nineteen years. — Rad. *de Diceto*, col. 528. "Stephen," says Holinshed, vol. iii. fol. 50, "began to repent himself, although too late, for that he had granted license to so many of his subjects to build castles within their own grounds

An art, Dr. Henry observes, (*History of Britain*, vol. vi. p. 188, 8vo.) so much practised as architecture was in this period, must have been much improved. That it really was so, will appear from the following very brief description of the most common form and structure of a royal castle, or of that of a great earl, baron, or prelate, in this period; and as these castles served both for residence and defence, this description will serve both for an account of the domestic and military architecture of those times, which cannot well be separated.

The situation of the castles of the Anglo-Norman kings and barons was most commonly on an eminence, and near a river; a situation on several accounts eligible. The whole site of the castle (which was frequently of great extent and irregular figure) was surrounded by a deep and broad ditch, sometimes filled with water, and sometimes dry, called the *fosse*. Before the great gate was an outwork, called a *barbacan*, or *antemural*, which was a strong and high wall, with turrets upon it, designed for the defence of the gate and drawbridge. On the inside of the ditch stood the wall of the castle, about eight or ten feet thick, and between twenty and thirty feet high, with a parapet, and a kind of embrasures, called *crennels*, on the top. On this wall, at proper distances, square towers, of two or three stories high, were built, which served for lodging some of the principal officers of the proprietor of the castle, and for other purposes; and on the inside were erected lodgings for the common servants or retainers, granaries, storehouses, and other necessary offices. On the top of this wall, and on the flat roofs of these buildings, stood the defenders of the castle, when it was besieged, and from thence discharged arrows, darts, and stones, on the besiegers. The great gate of the castle stood in the course of this wall, and was strongly fortified with a tower on each side, and rooms over the passage, which was closed with thick folding-doors of oak, often plated with iron, and with an iron portcullis, or grate, let down from above. Within this outward wall was a large open space, or court, called, in the largest and most perfect castles, the *outer bayle* or *ballium*, in which stood commonly a church or chapel. On the inside of this outer bayle was another ditch, wall, gate, and towers, enclosing the inner bayle, or court, within which the chief tower, or keep, was built. This was a very large square fabric, four or five stories high, having small windows in prodigious thick walls, which rendered the apartments within it dark and gloomy. This great tower was the palace of the prince, prelate, or baron, to whom the castle belonged, and the residence of the constable or governor. Under ground were dismal dark vaults, for the confinement of prisoners, which made it sometimes be called the dungeon. In this building, also, was the great hall, in which the owner displayed his hospitality, by entertaining his numerous friends and followers. At one end of the great halls of castles, palaces, and monasteries, there was a place raised a little above the rest of the floor, called the *dais*, where the chief table stood, at which persons of the highest rank dined. Though there were unquestionably great variations in the structure of castles and palaces in this period, yet the most perfect and magnificent of them seem to have been constructed on the above plan. Such, to give one example, was the famous castle of Bedford, as appears from the following account of the manner in which it was taken by Henry III. A. D. 1224, from Matthew Paris, *Hist. Angl.* p. 221-2. The castle was taken by four assaults. "In the first was taken the barbacan; in the second, the outer ballia; at the third attack, the wall by the old tower was thrown down by the miners, where, with great danger, they possessed themselves of the inner ballia, through a chink; at the fourth assault, the miners set fire to the tower, so that the smoke burst out, and the tower itself was cloven to that degree, as to show visibly some broad chinks; whereupon the enemy surrendered."

As Britain abounded in this period in fortified towns and castles, much of the art of war, of course, consisted in defending and assaulting strong places; and a knowledge of the application of them in this period may be obtained from the relation of the siege of Exeter castle by king Stephen, in the year 1136. See the *Gesta Regis Stephani*, apud Duchesn, p. 934. It is perhaps the most consummate specimen of the military skill of that age with which we are acquainted. And it may be enough to observe, that after this siege had lasted three months, and king Stephen had expended upon it in machines, arms, and other things, no less than 15,000 marks, equal in efficacy to 150,000 pounds of our money, the besieged were obliged to surrender for want of water. Henry's *Hist. of Britain*, vol. vi. p. 217.

Berkeley, which was originally founded in the reign of Stephen, is one of the best remains we are now possessed of, of an ancient feudal castle. But the changes which almost all these buildings have undergone in subsequent times, may be judged of by those which have taken place at Berkeley. The buildings within the inmost only of the three gates are said to have been the work of Henry II. when duke of Normandy; while the two outermost, with all the buildings belonging to them, except the keep, are referred to the latter end of the reign of Henry II. and to those of the second and third Edwards. The hall and the two chapels are of the latter period; and the great kitchen, adjoining to the keep, was of the work of Henry VII.

Among the castles which Mr. King has endeavoured to appropriate to the early Norman period, are those of Nottingham, Lincoln, and Clifford's tower at York, all erected by the Conqueror: *Archæol.* vol. vi. p. 257. The remains of all these, he observes, fully illustrate the Norman mode of constructing such edifices. Tickhill, in the neighbourhood of Doncaster, appears to have been another of these castles, *ibid.* 267; and Pontefract bespeaks a Norman design, with rude and imperfect alterations. All of these appear to have been erected upon artificial mounts, and nearly cover the whole area of the summit of the respective hills on which they are situated.

Tunbridge castle, in Kent, built by Richard de Clare, about the time of William Rufus, is mentioned by Mr. King, as a specimen of the later Norman structures; and he has been very accurate in his description of it; *ibid.* 270. Gundulph, who directed the building of the Tower of London, in 1078, and the castle at Rochester, he describes to have introduced a great many judicious alterations, and not only to have increased the security, but the magnificence of our military piles; and observes that the castle at Rochester is a complete specimen of all that he effected. Newark, which Mr. King afterwards mentions, is an instance of a prelate's castle in the reign of Stephen: and the keep of Knaresborough, of the time of Henry III., completes the specimens it may be proper to mention of the irregular style of castle-building which prevailed during the interval between the Norman Conquest and the middle of the thirteenth century.

To these succeeded the magnificent piles of Edward I., more convenient and more stately, and containing not only many towers, but great halls, and sometimes even religious houses. The best style of military architecture in this period was displayed in the castles of Caernarvon, Conway, and Caerphilly; and it is singular to observe that many of our more ancient castles were then increased with additions in the same sumptuous style.

After the age of Edward I. we find another kind of castle introduced, approaching nearer to the idea of modern palaces. The first of these was that at Windsor, built by Edward III., who employed William of Wykeham as his architect. This convenient and enlarged style of building was soon imitated, on a lesser scale, by the nobles of the realm; and two remarkable instances, wherein convenience and magnificence were singularly blended at this period, may be found in the castles of Harewood and Spofford, in Yorkshire. The improvements at Kenilworth afford another instance of the great enlargement which our castles, during this age, were accustomed to receive: and Naworth, in Cumberland, is another of the best specimens that can probably be referred to. Caistor, in Norfolk, affords the style of Henry the Sixth's reign. It was built by Sir John Fastolf, who died in 1459.

To these venerable piles succeeded the castellated houses; mansions adorned with turrets, and battlements; but utterly incapable of defence, except against a rude mob, armed with clubs and staves, on whom the gates might be shut; yet still mansions almost quite devoid of all real elegance, or comfortable convenience, and fitted only to entertain a herd of retainers wallowing in licentiousness. At the same time, however, they discover marks of economy and good management, which enabled their hospitable lords to support such rude revels, and to keep up their state even better than many of their more refined successors. Of these buildings one of the most perfect and most curious, now remaining, is Haddon House, in Derbyshire; castellated and embattled, in all the apparent forms of regular defence; but really without the least means of resistance in its original construction. The description Mr. King has given of it, *Archæol.* vol. vi. p. 347, is, however, too long to be extracted, and too curious to be abridged.

After this kind of building, the magnificent quadrangular houses of the reign of Henry VIII. succeeded; of which the most beautiful and genuine models, perhaps, were those of Cowdray, in Sussex, and Penshurst, the seat of the Sidney family, in Kent.

Without referring to the stately buildings of Elizabeth's reign, it may be enough to say, that here ends the history of the English castle. The block-houses of Calshot, Hurst, Sandown, Sandgate, and South Sea, are the last instances of such buildings ever intended for a stand, and seem strongly to mark the revolution which has taken place in our defensive system of war.

The total change in military tactics, brought about by the invention of gunpowder and artillery; the more settled state of the nation, Scotland becoming part of the dominions of the kings of England; the respectable footing of our navy, whose wooden walls secure us from invasions; and the abolition of the feudal system,—all conspired to render castles of little use or consequence, as fortresses: so the great improvement in arts and sciences, and their constant attendant, the increase of luxury, made our nobility and gentry build themselves more pleasant and airy dwellings; relinquishing the ancient dreary mansions of their forefathers, where the enjoyment of light and air was sacrificed to the consideration of strength; and whose best rooms, according to our modern refined notions, have more the appearance of gaols and dungeons for prisoners, than apartments for the reception of a rich and powerful baron.

However, in the reign of Charles I., a little before the breaking out of the civil war, some inquiry into the state of these buildings seems to have taken place; for on the 22nd of January, 1636, a commission was issued, appointing lieutenant-colonel Francis Coningsby, commissionary general of and for all the castles and fortifications in England and Wales, with an allowance of 13s. 4d. a day, to be paid out of the cheques and defalcations that should be made by him from time to time; or, in default thereof, out of the Treasury. Whether this office was really instituted for the purpose of scrutinizing into the state of these fortresses, as foreseeing the events which afterwards happened; or whether it was only formed to gratify some favourite, does not appear. During the troubles of that reign, some ancient castles were garrisoned and defended, several of which, particularly Corfe castle, in Dorsetshire, were afterwards destroyed, by order of the parliament: since that period, they have been abandoned to the mercy of time, weather, and the more unsparing hands of avaricious men. The last have proved the most destructive; many of these monuments of ancient magnificence having been by them demolished for the sake of the materials: by which the country has been deprived of those remains of antiquity, so essential, in the eyes of foreigners, to the dignity of a nation; and which, if rightly considered, tended to inspire the beholder with a love for the now happy establishment; by leading him to compare the present with those times when such buildings were erected: times when this unhappy kingdom was distracted by intestine wars; when the son was armed against the father, and brother slaughtered brother; when the lives, honour, and property of the wretched inhabitants depended on the nod of an arbitrary king, or were subject to the more tyrannical and capricious wills of lawless and foreign barons.

The few castles existing in the Saxon time, were, probably, on occasion of war, or invasions, garrisoned by the national militia, and, at other times, slightly guarded by the domestics of the princes or great personages who resided in them; but after the Conquest, when all the estates were converted into baronies, held by knight's service, castle-guard, coming under that denomination, was among the duties to which particular tenants were liable. From these services the bishops and abbots, who, till the time of the Normans, had held their lands in frank-almoign, or free alms, were, by this new regulation, not exempted; they were not, indeed, like the laity, obliged to personal service, it being sufficient that they provided fit and able persons to officiate in their stead. This was, however, at first vigorously opposed by Anselm, archbishop of Canterbury; who, being obliged to find some knights to attend King William Rufus in his wars in Wales, complained of it as an innovation and infringement of the rights and immunities of the church.

It was no uncommon thing for the Conqueror, and the kings of those days, to grant estates to men of approved fidelity and valour, on condition that they should perform castle-guard, with a certain number of men, for some specified time; and sometimes they were likewise bound by their tenures to keep in repair some tower or bulwark, as was the case at Dover castle.

In process of time, these services were commuted for annual rents, sometimes styled *ward-penny*, and *wayt-fee*, but commonly *castle-guard rents;* payable on fixed days, under prodigious penalties, called *sur-sizes.* At Rochester, if a man failed in the payment of his rent of castle-guard on the feast of St. Andrew, his debt was doubled every tide, during the time for which the payment was delayed. These were afterwards restrained by an act of parliament, made in the reign of King Henry VIII., and finally annihilated, with the tenures by knight's service, in the time of Charles II. Such castles as were private property, were guarded either by mercenary soldiers, or the tenants of the lord or owner.

Castles which belonged to the crown, or fell to it either by forfeiture or escheat (circumstances that frequently happened

in the distracted reigns of the feudal times) were generally committed to the custody of some trusty person who seems to have been indifferently styled *governor* or *constable.* Sometimes also they were put into the possession of the sheriff of the county, who often converted them into prisons. That officer was then accountable to the exchequer, for the farm or produce of the lands belonging to the places entrusted to his care, as well as all other profits: he was likewise, in case of war or invasion, obliged to victual and furnish them with munition out of the issues of his county; to which he was directed by writ of privy seal. Variety of these writs, temp. Edw. III., may be seen in Madox's *History of the Exchequer;* and it appears, from the same authority, that the barons of the exchequer were sometimes appointed to survey these castles, and the state of the buildings and works carrying on therein.—Rees's *Cyclopedia.*

CASTRA, the Latin name for a camp.

CASTS. *See* CAST and CASTING.

CATABASION (from καταβαινω, *I descend*), in the Greek church, a hollow place under the altar, wherein the relics were kept, and through which was the descent into the vaults beneath.

CATABULUM, a building, or stable, in which the beasts of burden and carriages were kept for the public service. The ancient Christians were sometimes condemned to serve in the catabula.

CATACAUSTIC CURVE. *See* CAUSTIC CURVE.

CATACOMB, a grotto or subterraneous place for the interment of the dead.

In Italy, this term is particularly applied to an assemblage of subterraneous sepulchres, three leagues from Rome, in the Via Appia. Each catacomb is three feet wide, and eight or ten feet high, running in the form of an alley or gallery, and communicating with each other. Some authors imagine them to be the cells wherein the primitive Christians hid themselves; and others take them to be the burial-places of the early Romans, before the practice of burning the dead was introduced.

The most celebrated catacombs are those of Egypt, wherein the ancient inhabitants deposited their mummies. The descent into them is through a square aperture with holes in the sides, for the feet, somewhat like an upright ladder. These excavations are hewn out of the solid rock, which consists of free-stone, and the walls are adorned with hieroglyphics, and representations of utensils and implements of war. *See* Pocock, Norden, and Denon.

CATADROME, an engine used in building, for lifting and letting down great weights.

CATAFALCO (from the Italian), a decoration, of architecture, sculpture, or painting, raised on a scaffold, on which to exhibit a coffin or cenotaph, in a funeral solemnity.

CATCH-DRAIN, in the construction of canals, the same as counter-drain; sometimes it also implies the feeders of a reservoir.

CATENARIA, a mechanical curve, which a heavy flexible body, of uniform thickness, would form itself into, if hung freely from its two extremities. The famous Galileo first investigated the nature of this curve, and supposed it to be a parabola. This problem, after being proposed by Mons. J. Bernouillé, was first solved by Dr. D. Gregory, who also affirmed, that the inverted catenaria was the best figure for the arch of a bridge; the intrados of which, however, must depend entirely upon the curvature of the extrados.

CATHEDRAL, (from the Greek, καθεδρα, *a chair;* derived from καθεζομαι, *sedeo*, I sit,) the head church of a diocese, wherein is the see or seat of a bishop.

During the first ages of the church, cathedrals were probably more numerous than other churches, as we know that there was a bishop in every town of importance wherever the Christian religion prevailed. The bishop, the head of the church, was assisted in the services of religion by his priests and deacons, the bishop, however, retaining the more important duties, such as preaching and the administration of the sacraments, which he seldom delegated to the assistant presbyters, unless necessitated so to do. In process of time, as occasion offered, other churches were formed, subject to the mother-church, and to the jurisdiction of its bishop; at this early period, however, it cannot be doubted but that the proportion of bishops to the lower order of the clergy was much greater than at the present day, and consequently the number of cathedrals or bishops' sees must have been more numerous. It is not our intention, however, in this place, to dwell at length upon the general subject; we would confine ourselves more especially to our own country, and will accordingly proceed to investigate the accounts we have left us of the early cathedrals of Great Britain.

No one, probably, would think of controverting the fact of the early introduction of Christianity into this country; it may indeed be questioned whether Saint Paul, or Saint Joseph, or the British king Lucius, be the benefactor to whom we owe its introduction; but its existence here during the first century will scarcely admit of a doubt. We know further that the British church was episcopally governed, for we hear of the presence of British bishops at the council of Arles, as early as the commencement of the fourth century; and we have consequently every reason to conclude that the episcopal form of government was co-existent with the church, and further, that if churches existed at all, some such churches must have been cathedrals.

We cannot speak with any degree of certainty of the date, form, or material of the first cathedrals. Dr. Milner says, that a cathedral was erected by Lucius, at Winchester, of the enormous length of 600 feet, as early as the close of the second century. Whether the dimensions given do not belie the whole statement must be left to the judgment of individuals; but there is good reason to believe that churches did exist at this period, as we hear of their demolition during the Diocletian persecution, which took place A. D. 303.

Upon the success of the Pagan-Saxons, the Christian churches of England were of course destroyed, whilst those in Wales and south-west of England, where the British Christians had retreated, were considerably increased; this was especially the case with monasteries, which served in a measure as places of safety, and in building which the Britains followed the salutary advice of Saint Germain. Upon the conversion of the Saxons by Saint Augustine, churches again made their appearance in Kent, as we learn that a cathedral was erected by that missionary-bishop at Canterbury, and dedicated under the title of Christ Church. At a not much later period we hear of the foundation of the cathedral churches of Saints Paul and Andrew, the one at London and the other at Rochester. Shortly after Augustine's mission in the south, the wonderful success of Paulinus in the northern parts of the island, in converting the king, Edwin, and his pagan subjects, gave rise to the cathedral of York. It is stated that Edwin first erected a church of timber in this city, but afterwards built a larger church of stone, in which the timber one was enclosed. Paulinus, again successful at Lincoln, caused to be erected a church of stone, of "admirable workmanship," as Bede tells us.

Stephen Eddy, a writer older than Bede, informs us that Wilfrid, bishop of York, finding, upon taking possession of his see, that the old church built by Edwin and Oswald was in a dilapidated condition, set about repairing it—"skilfully

roofing it with lead, and preventing the entrance of birds and rain by putting glass into the windows, yet such glass as allowed the light to shine within;" and our author goes on to state that the same Wilfrid built a new church at Ripon, of polished stone, "with columns variously ornamented, and porches." The account of the dedication of this church is given in full, and is the earliest description of the kind extant.

A curious and somewhat detailed account is given by the Monk of Ramsey, of the construction of the church at Ramsey existing previously to the one dedicated in his time. He says, "it was raised on a solid foundation, driven in by the battering-ram, and had two towers above the roofs: the lesser was in front at the west end; the greater, at the intersection of the four parts of the building, rested on four columns, connected together by arches carried from one to the other." He further adds, that this church was obliged to be pulled down, and a new one erected in its stead, in consequence of a settlement in the central tower, which rendered the entire building unsafe.—That this church was of stone can scarcely be doubted, after perusing the above narrative; but we have direct and explicit mention of the fact, for the same author, in describing the labours of the workmen, says: "Some brought the stones, others made the cement, while others attended to the machines for raising the stones; so that in a short time was seen the sacred edifice with its two towers, where previously there had been but a barren waste."

A curious representation of an Anglo-Saxon church is to be seen in an Illuminated Pontifical in the Public Library at Rouen, containing the order for the dedication and consecration of churches; the date of which is ascribed by some to the eighth, and by others to the tenth, century; that the manuscript is of English origin has never been doubted. This miniature in black outline represents the ceremony of dedication. The form of the church is remarkably similar to that of our existing cathedrals, which is more especially noticeable in the form of the towers and spires, the symbolical cock on the steeple, and the ornamental hinges of the door.

We are here naturally led into some inquiry respecting the materials, form, and disposition of these early cathedrals. The materials employed by the Anglo-Saxons seem to have been wood and stone, but during what time either material was used cannot easily be determined; whether they were both used at the same period, under different circumstances, or whether at any point of time the one was superseded by the other, we are unable to learn. It has been supposed, and with some plausibility, that wooden churches were erected by the Scotch and Irish missionaries, and the more substantial fabrics by those from Rome, and this idea seems to be borne out by Bede, who states "that Adrian, the first bishop of Lindisfarne, having departed this life, Finan, sent and ordained by the Scots, succeeded him, and built a church in the island after the method of the Scots; which was built not of stone, but of hewn oak, and covered with reeds." This writer adds, that "Eadbert, the seventh bishop, took off the thatch, and covered both the walls and roof with lead." It seems very reasonable likewise that the Roman missionaries, who had been used to the structures of Italy, should not feel satisfied with mere wooden buildings. It is true it seems to be noted as somewhat unusual, that Wilfrid built a church at Ripon of polished stone, yet the novelty may not have consisted in the erection being of stone, but rather in the fact of the stone being smoothed or polished; for it is probable that the first buildings, after the Roman manner, were of rough undressed stone, there being neither time, means, nor workmen to complete a more finished structure. It is very probable that Wilfrid's church was built by Italian workmen, as we know that he had frequented Rome, and was a man too zealous in promoting the temporal splendour of the church, to allow any opportunity of forwarding his object to slip past unimproved. There can be little doubt but that in process of time the employment of stone entirely superseded that of timber.

No inconsiderable notion is afforded us of the form and disposition of the parts of the early cathedrals, from an account already referred to—we allude to that of the church at Ramsey. From this description we gather that the plan of the church was cruciform, with a tower rising from the intersection, and another at the west end of the church.

We learn from Wolstan, that there was a tower at the west end of the old church at Winchester, but that in the new structure the tower was towards the eastern extremity, and of the last it is related that it consisted of five stories, in each of which were four windows looking towards the cardinal points.

Further, in the miniature of the Illuminated Pontifical above described, we notice that the tower is surmounted by a steeple, a fact which, were it not for other considerations, would almost tempt us to refer the manuscript to a much later date, as we know that such additions were not very frequent, even in the Norman period; indeed, the idea of a Saxon cathedral afforded us by these descriptions, approaches very nearly to actual existing specimens of much later date. We must not conclude from these accounts that all churches of this date were cruciform, for we learn the contrary from Bede, who speaks of churches as square; some have supposed that Ramsey was the first instance of a cruciform edifice, but this was not the case, as is evinced by a metrical description of a cathedral, written long before its erection.

Having thus far considered the nature of the Saxon cathedrals, we arrive at the Norman era, during which a great number were erected; but as we have no lack of existing examples of this period, we do not think it requisite to pursue a detailed inquiry any further: we shall now proceed to some description of the cathedrals of the present day.

The term Cathedral includes generally the whole of the buildings connected with the bishop's see, including the church, chapter-house, chapels, cloisters, dormitories, refectories, residences for those engaged in attendance on the bishop, and in the services of the cathedral, and buildings for a variety of uses; it is applied, however, in a more especial sense, only to the church, and to such application we shall confine ourselves in the following remarks.

The plan of our old cathedral churches is invariably that of a Latin cross, having the nave in the longest arm, the transepts in the two cross arms, and the choir, comprising the remaining length of the church, to the east of the nave; the English always placing their altar at the east end, which was more frequently square, than either circular or multangular, as in the continental churches. Not unusually the plan was extended further eastward, to provide for an additional chapel, dedicated to our Ladye, and sometimes, though much less frequently, a similar, but smaller projection, was added at the west end: this was the Galilee porch, so named, as we learn from Gervase, from the passage of Scripture—"He goeth before you into Galilee, there ye shall see him,"—this being the place where the monks were allowed to see their female relatives; here was also the station of catechumens, and the resting-place of corpses previous to their interment. In some instances we find a double transept, east and west of each other, as at Canterbury; the additional arm is accounted for symbolically as representing the inscription placed above

the head of our Lord at his crucifixion, the lower symbolizing the cross-piece on which the arms were extended. It is noticed in some cathedrals that the eastern extremity is not in the same line with the nave, but bent on one side, as it were; this is explained in a similar manner as marking the inclination of the head of our Lord while on the cross. At the west end of the nave, on each side of it, were situated the towers, and another at the intersection of the nave and transepts, all of which were in some cases surmounted with spires; sometimes this addition was restricted to the western towers, but it is frequently omitted altogether, when the towers are usually carried to a greater elevation. At Exeter, we meet with the towers forming the transept, and at Peterborough with one at the northern extremity of the west transept. Internally the nave and choir are divided into three aisles, the central one being carried up above the others. This tripartite division is seldom carried out in the transepts, in which, however, we sometimes find one aisle as at Durham, and sometimes two as at Westminster and Bristol. The aisles are separated from the body of the church by an arcade, immediately above which the vaulting commences; in the body, however, between the arcade and vaulting, are interposed two stories, the lower one consisting of a gallery called triforia, opening into the nave and choir by means of a small arcade, and supposed to have been appropriated to the nuns; and the upper, termed the clere-story, in which were placed the windows for lighting the central avenue of the church. In Bath Cathedral, the triforia are omitted, and their place supplied by a string-course.

An approximation to the proportions of the different measurements of cathedral churches is given by Brown Willis, as follows: — The height is generally equal to the breadth of the nave and aisles; the cross, in which the transepts and intermediate space are contained, is extended half the length of the whole fabric, as is likewise the nave; the side-aisles equal half the breadth and height of the nave, and the spires and tower have a mean proportion between the length of the nave and that of the transept.

The above description will give a general idea of the construction of our cathedrals; but from the exceptions already noticed, it will be understood that no rule applies invariably to all buildings of the kind; for although the plans are in all cases similar, and the arrangement of the parts of the edifice systematic, yet we find not one cathedral in any respect a copy of another.

We now proceed to give some account of the edifices of this rank preserved to us in the present day, of which we have 21 in England, and 4 in Wales. There were also 13 in Scotland, and 22 in Ireland. In addition to the number already mentioned, we have in England one modern cathedral, Saint Paul's, London; besides which the collegiate church at Manchester has recently been elevated to the dignity of a bishop's see; but as the latter was never constructed for such a purpose, we do not think it can be correctly included with the others as an architectural example.

The following is an account of the erection of cathedral churches in England, and additions made to them, arranged in chronological order: —

To the period of the Anglo-Normans, or between 1066 and 1170, including the reigns of William I. and II., Henry I., Stephen, and the first sixteen years of Henry II., we may attribute the western front and nave of Rochester cathedral; the nave, north aisle, and the chapels round the choir of that at Gloucester; the original substructure of Exeter cathedral, with its transepts and towers; the central tower and transept of Winton cathedral; the nave of that at Chichester; the north transept of that at Ely; the choir of Peterborough cathedral; the oldest part of the western front and central tower of that at Lincoln; the central church of Durham, excepting the additional transept on the east; the nave and tower of Norwich; and many arches of Worcester cathedral.

In the period between 1170 and 1220, including the latter part of the reign of Henry II., and the reigns of Richard I. and John, the older Ladye chapel and chapter-house of Bristol were erected; as were likewise the choir and round tower (called Becket's Crown) at Canterbury; the nave and chapter-house at Oxford; the nave and choir of Norwich cathedral; the western towers at Ely; the transepts of Peterborough; the presbytery, Chichester; the transept, tower, and choir of that at Hereford; the nave and choir of Wells cathedral (begun); and the chapter-house of Chester.

In the period between 1220 and 1300, including the reigns of Henry III. and part of Edward I., were erected the nave and arches beyond the transept of Lincoln cathedral; the north and south transepts of York minster; the choir and transept, Rochester; an additional transept to the cathedral of Durham; the tower and whole western front of that of Wells; the choir at Carlisle; the presbytery and south transept at Ely; the transept and choir at Worcester; and the whole of Salisbury cathedral.

In the period between 1300 and 1400, including the latter part of the reign of Edward I, and the reigns of Edward II. and III. and Richard II., the nave and choir of Exeter cathedral were erected; and that at Lichfield was built uniformly; additions were made to the central tower at Lincoln: the nave of Worcester cathedral was built, as were the nave, choir, and western front of York minster; also the transepts at Canterbury and Gloucester; the spire and tower at Norwich; the spire and additions to Salisbury cathedral; the cloisters were begun at Gloucester: the nave and choir were erected at Bristol, as well as the spire and choir at Chichester; our Lady's chapel at Ely; and the chapter-house and cloisters (now destroyed) at Hereford.

In the period between 1400 and 1460, including the reigns of Henry IV., V., and VI., were erected the choir of Gloucester cathedral; the nave of that of Canterbury; Bishop Beckington's addition to Wells cathedral; and that of Lincoln, from the upper transept to the great east window.

In the period between 1460 to 1547, viz., from the reign of Edward IV. to the end of that of Henry VIII., were erected our Lady's chapel at Gloucester; the roof of the choir of Oxford cathedral; the choir of that of Chester; Alcocke's chapel at Ely; the Ladye chapel, Peterborough; the north porch, Hereford; and the exterior of the choir at Winchester.

The following particulars respecting the English Cathedrals are extracted principally from the works of Britton and Dallaway: —

PECULIARITIES.

Bath — The unusual height of the clere-story.

Bristol — Had no nave, the present choir being formed out of the Ladye chapel.

Canterbury — The grand entrance is under the south tower. The marble columns of the choir with Romanesque capitals, and the octangular chapel called Becket's Crown.

Chester — Extraordinary size of the south transept.

Chichester — Double aisles to nave, and detached campanile at its north-west angle.

Durham — The chapel of our Ladye placed at the east end as a second transept; the Galilee placed before, and distinct from the façade.

Ely — A single western tower connected with the nave; — the

octangular tower; —the Ladye chapel detached from choir, and a Galilee in a perfect state.

Exeter — The skreen before the west front, and towers at either end of the transept. This cathedral was completed according to the original plan.

Lincoln — The arches in the west front, the work of Remigius; the Galilee and double transept.

Lichfield — The three stone spires.

Norwich — The roof of the nave, and the west end, with the Erpingham gateway.

Peterborough — The triple arcade before the west front eighty-two feet high; the double towers with spires at the western angles; tower at the southern extremity of the north-west transept, and the Galilee.

Rochester — The choir longer than the nave.

Salisbury — The complete uniformity of style; the height of the central spire, and the double elliptic inverted arch under the tower, as at Wells.

Winchester — The longest nave.

York — The double aisles to the transept; the largest window; the square louvre, and the absence of cloisters.

Remarkable Parts.

Bath — The tower has four turrets, without pinnacles, and is oblong in plan, which is owing to the narrowness of the transept; the aisles are very low, and there is no triforium in the nave, but merely a plain string-course. There is an alto-relievo of Jacob's ladder at the west end.

Bristol — Has no external flying buttresses, the walls of the nave being supported by the roofs of the aisles, which are formed of complicated open arches; the aisles and nave are of equal height, only forty-three feet.

Canterbury — The crypt, which is of greater extent, and more lofty than any other in England; the central tower and the apsidal form of the east end.

Chester — The unequal dimensions of the north and south transepts, the latter being wider, and nearly as long as the nave, with aisles on each side, while the former is unusually short, and of the same width as the central tower; the aisles of the choir also extend beyond it eastward, and form the aisles of the Ladye chapel.

Chichester — Has the earliest specimen of a vaulted roof; its spire greatly resembles that of Salisbury.

Durham — Pillars of nave curiously striated; the Galilee measures 50 feet by 78 feet.

Exeter — Possesses almost the only example of a group in sculpture, which is in the triforia of the transept, and represents a concert of musical instruments.

Ely — The octangular lantern, which is 71 feet in diameter, and 142 feet from the ground, supplied the place of a lofty central tower which fell down a short time previous to the erection of the lantern. There exists one of the earliest specimens of the pointed arch in the tower and transept.

Gloucester — The eastern termination is apsidal; and the cloisters, the most perfect and beautiful in England, unusually situate on the north side of the church.

Lincoln — Old west front; the large and beautiful south porch, and east façade; the Galilee. The central tower had a spire higher than Salisbury, which was blown down A. D. 1547. This church is remarkable for its sculpture, and has a curious bas-relief of the Deluge over the west door, and of the Last Judgment over the south porch.

Lichfield — Is nearly uniform, and was completed throughout on the original plan. The east end is apsidal in plan.

Norwich — The end of the choir is octangular, and the cloisters are very spacious.

Peterborough — The grand façade and portico, remarkable for their fine proportions; the Galilee and aspidal termination, also the west transept, which is placed at the west end.

Rochester — The west façade is one of the most perfect specimens of Norman; the choir is longer than the nave.

Salisbury — Is the most uniform cathedral in England, and has a lofty and beautiful spire, only seven inches thick.

Wells — The west front is noted as bearing a resemblance to the façades of Continental cathedrals; it is filled with statues; the central tower is supported on an inverted arch as at Salisbury.

Winchester — Is remarkable for its fine nave; the choir is under the central tower.

Worcester — The style and proportions of the nave are considered beautiful.

York — The aisles surrounding the whole church are of the same dimensions throughout; the rose window, which is 22 feet 6 inches in diameter, is the finest in England; the choir is under the tower, as at Winchester.

The subjoined Tables may be found useful; the former, from the works of Dallaway, gives the dates of the principal portions of the English Cathedrals; the latter, compiled principally from Britton's Antiquities, shows their dimensions. It will be noticed that Mr. Dallaway's dates do not agree in every case with those above given.

Dates of the Principal Portions of the English Cathedrals.

Cathedrals.	Nave.	Choir.	Aisles.	Transept.	Tower.
Bath	1532	1500	1532 na. 1570 ch.	1500 1532	1500
Bristol	1332	1332		1311 S. 1463 N.	1463
Canterbury	1420	1174	1174	1174 up. 1379 lwr.	1070 N. W. 1400 S. W. 1500 Cent.
Carlisle	1150	1363	1150 na. 1363 ch.	1353	1400
Chester	1485		1485	1320 N.	1508
Chichester	1125	1217	1125 na. 1217 ch.	1217 N. 1329 S.	1217 W. 1282 Cent.
Durham	1093	1233		1230	1230 W. 1295 Cent.
Ely	1174	1235		1133 N.	1174 W. 1328 Cent.
Exeter	1307	1318	1307 na. 1318 ch.	1280	1128
Gloucester	1089	1357	1089 na. 1310 ch.	1330 S. 1375 N.	1457
Hereford	1095	1115	1095	1095 up. 1148 lwr.	1216 W.
Lichfield	1295	1295	1295	1295	1295 W. 1430 Cent.
Lincoln	1200	1200	1200	1300 W. 1306 E.	1254 Cent. 1279 W.
Norwich	1171	1195	1171 na. 1160 ch.	1195	1096
Oxford	1120	1120	1120	1122	1222
Peterborough	1175	1160	1175 na. 1160 ch.	1272 W.	
Rochester	1080	1227	1080 na. 1227 ch.	1080	
Salisbury	1217	1230	1217 na. 1230 ch.	1274	1217
Wells	1239	1239	1239	1239	1450 W. 1465 Cent.
Winchester	1394	1493	1394 na. 1493 ch.	1070	1070
Worcester	1218	1218	1218	1218 lwr. 1380 up.	1372
York	1291	1361	1291 na. 1361 ch.	1227	1361 W. 1420 Cent.

Admeasurements of the principal parts of the most remarkable Cathedral Churches of Great Britain, given in English feet. A large portion of this Table is extracted from Britton's Works.

Cathedrals.	Extreme Length.		Extreme Breadth.		Nave.				Choir.			Transept.			Centre Tower.	West Towers	West Front.	
	Exterior.	Interior.	Exterior.	Interior.	Length.	Breadth.	Breadth with aisles.	Height.	Length.	Breadth with aisles.	Height.	Length.	Breadth.	Height.	Height in Pinnacles.	Height.	Breadth at Ground.	Height.
[a] Canterbury	545	516	170	158	188	27	73	80	132	86	76	158	40	75[1]	230	153[3]	93	107
												128	34	79[2]				
York	518	480	241	220	210	43	110	93	130	100	100	220	98	93	200	196	140	137
Bristol	203	174	127	113	...	..	...	...	76	69	54	174	29	50	133			
Carlisle	242	210	130	116	...	..	...	...	107	72	...	116	18					
Chester	375	312	112	100	120	41	84	...	80	84	...	100	44		...	...		
[b] Chichester	410	386	151	131	146	26	100	65	68	60	65	131	34	65	300[5]	95[6]		
Durham	507	476	194	170	203	37	82	70	93	79	70	170	59	...	210	143	117	105
[c] Ely	535	517	190	179	203	30	74	...	101	74	70	179	78	...	170[7]	215	142	112
Exeter	408	382	155	140	96	31	72	66	123	72	66	140	30	72	153	...	113	100
Gloucester	427	406	154	142	160	33	35	68	110	83	85	142	35	70	223	...	95	88
[d] Hereford	350	326	174	145	125	28	70	63	76	72	60	145	53[8]	60	160	...	95	
												106	35[9]					
[e] Litchfield	403	379	177	149	143	26	66	58	145	69	57	149	45	57	252[11]	200[12]	100	93
[f] Lincoln	505	440	242	218	176	37	78	81	118	80	75	218	61	74	264	209	175	132
												165	37[13]					
[g] Norwich	415	384	200	180	205	28	70	75	130	72	85	180	28	72	309[14]	...	83	93
[h] Oxford	168	156	116	102	61	22	53	45	54	52	45	102	21	45	145[15]	...		
[i] Peterborough	480	427	198	184	234	35	79	73	90	79	...	183	58	73	143	150	153	115
																155[16]		
[k] Rochester	383	362	170	144	140	32	73	55	145	85	55	122	32	55	156	95	93	
												90	58	55[17]				
[l] Salisbury	474	450	230	206	196	32	78	81	152	78	81	206	57	81	404[20]	...	112	115
												145	44	81[19]				
Wells	415	385	155	130	164	32	70	68	82	32	73	130	68	68	165	125	148	115
Winchester	556	520	230	208	240	32	88	78	113	88	67	208	81	80	148	...	128	130
[m] Worcester	425	386	145	127	174	30	78	67	90	73	61	127	31	66	193	...		
												121	24	66[21]				
[n] St. Paul's	512	462	283	228	170	39	102	90	97	102	90	228	97	90	360[22]	210	177	138
[o] Old St. Paul's	...	690	...	...	...	..	130	102	165	42[24]	88	248	..	...	534[23]			
Westminster Abbey Church	530	475	215	195	154	30	68	105	136	72	105	195	73	105	...	225	110	141
St. Asaph	...	179	...	...	119	..	68	60	60	32	60	108	..	...	93			
Bangor	...	214	...	...	141	..	60	34	53	...	...	96	32	...	...	60		
St. David	...	307	...	...	124	..	76	46	80	...	...	148	..	...	...	127		
[p] Llandaff	...	270	...	...	...	..	80	...	...	...	...	...	..	...	...	90		
[q] Man	...	113	...	...	...	22	...	...	...	...	...	66						
[r] St. Patrick	...	300	...	...	...	..	...	...	...	...	...	157	..	...	223[25]			
Dunblane	...	216	...	...	...	..	...	...	...	...	...	76	..	...	...	120		
[s] Elgin	...	264	...	...	...	35	...	...	...	...	...	114	..	...	198[26]	84[27]		
[t] Glasgow	370	339	...	...	155	30	62	90	97	62	90	...	..	...	220[28]	120[29]		
Iona	...	160	...	...	...	..	...	...	...	...	...	70	..	...	75			
[u] Kirkwall	...	256	...	...	...	..	...	70	...	...	...	...	..	...	133[30]			

[a] Has two transepts: [1] East transept; [2] West transept; [3] South-west tower.
[b] [5] Including spire; [6] South-west tower.
[c] [7] Octagonal lantern; there is a projection or transept at the west end, forming a galilee.
[d] [8] North end with aisle; there are two transepts; [9] East transept.
[e] [11] and [12] With spires.
[f] Has two transepts: [13] East transept.
[g] [14] With spire.
[h] [15] With spire.
[i] Has projection or transept at the western extremity; [16] tower over north-west transept.
[k] Has two transepts; [17] East transept.
[l] Has two transepts; [19] East transept.
[m] Has two transepts; [21] East transept.
[n] [22] Top of cross over dome.
[o] [23] To top of spire; [24] without aisles.
[p] Has two western towers.
[q] No side aisles.
[r] [25] With spire.
[s] [26] With spire; [27] Without spire; length of ladye chapel eastward 28 feet, extending the whole width of the cathedral.
[t] [28] To the extremity of the spire; [29] At north-west angle.
[u] [30] With spire.

Many cathedrals of architecture similar to our own, are to be seen on the Continent, of the more noted of which we shall give a short description. One of the great points of distinction between the English and foreign cathedrals, is the superior magnitude of the latter, which is evidenced more in the height than in any other dimension:—a circumstance which will be apparent, when it is told that the west front of York Minster could be placed beneath the choir-roofs of Beauvais or Amiens cathedrals; the length of the continental buildings, however, does not bear so great a proportion to their breadth as in England, so that they lose that perspective effect afforded by the long vista of arcades which forms so beautiful a feature in our cathedrals. Another distinguishing characteristic in the foreign churches is afforded in the magnificence of the grand façades, of which full one moiety is occupied by the portal. In our works the entrance is of small dimensions, and is subservient to the window above it, but in theirs it forms the principal object, being splayed from the door to the exterior surface of the wall, and the space thus formed, occupied with columns,

niches, statues, and other embellishments; the upper part of this splay is of course of an arched form, and the tympanum over the door-head is frequently filled with large groups of sculpture. The upper half of the façade is occupied by a circular or rose window of great magnitude. This arrangement is frequently carried out in the ends of the transepts. Further we have to notice the apsidal forms of the east end, the numerous chapels surrounding the choir, and the great height of the roof, which in France is in a great measure concealed by lofty parapets, but in Germany, where it is even more lofty, is left exposed. Internally, the foreign structures are remarkable for the great height of the body and aisles, and simplicity of the vaulting; for the apsidal termination with its vaulted roof, and the size of the rose windows of the nave and transepts. The body of the building is frequently divided laterally into five parts, having a central nave with a double aisle on each side of it.

The following cathedrals are remarkable for their—

Entrance Porches—Rheims, Strasburg, and Rouen.

Rose windows—Strasburg, Notre Dame, S. Ouen, Rouen, and Rheims.

Towers and spires—Strasburg, Mechlin, Antwerp, Ulm, Cologne, Friburg, Louvain, and Vienna. The height of that of Strasburg is 550 feet; that of Louvain (now fallen) 533 feet; and that of Vienna, 465 feet. Strasburg, Friburg, and Constance, are noted for their spires of open work or pierced tracery.

The cathedrals of Freidburgh and Frankenburgh have the nave and aisles of the same height, and that of Freidburgh has the side aisles nearly as wide as the nave. St. Lorenzo, Nuremburgh, has a choir loftier than the nave, and the cathedral at Worms is celebrated for its two choirs.

S. Peter's, Rome, is the most spacious cathedral, after which follow those of Cologne and Milan, of which the former has never been completed; it was commenced in the middle of the thirteenth century, but the choir is the only portion that was finished, the nave is carried up only half its intended height. This building, if entire, would be perhaps the most magnificent cathedral in existence, but there seems but a remote probability of its completion: it is said to be adorned with 4,973 pinnacles, 576 statues, 128 windows, 160 flying buttresses, 104 pillars, and 9 entrances, while Milan boasts of 4,400 statues, and 160 columns of white marble.

Admeasurements of some of the more remarkable Continental Cathedrals, given in English feet.

Name of Cathedral.	Total length.	Nave.			Choir.			Aisles.		Transept.		Breadth of façade.	Breadth of nave with aisles.	Height of central tower.	Height of west tower.
		Length.	Breadth.	Height.	Length.	Breadth.	Height.	Breadth.	Height.	Length.	Breadth.				
[a] Amiens	415	220	42	132	130	42	129	18	..	180	42	150	...	...	210
[b] Bayeux	296	140	48	76	118	36	...	17	..	113	..	...	...	224	230
Chartres	376	222	46	108	114	46	...	21	..	195	40	...	103	...	378[1]
Notre Dame	492	244	42	...	157	38	...	..	..	...	..	...	...	...	221
[e] Rheims	439	...	38	116	...	..	...	22	..	150	93	140	93	...	253
[f] Rouen	408	...	..	90	...	..	...	..	..	164	..	...	93	532[2]	...
[g] S. Ouen	416	244	34	100	102	..	...	..	..	130	..	...	...	240	...
[h] Antwerp	500	...	..	...	...	..	...	..	..	230	..	...	...	466	360
[i] Cologne	532	...	..	160	...	..	160	..	80	250	..	...	...	432	532
Friburg	399	...	..	86	...	..	...	..	..	...	..	...	...	...	372
Ulm	416	...	..	140	...	..	...	..	..	...	..	166	...	...	490
[k] Florence	491	132	..	139	...	..	...	..	..	294	..	...	...	463	..
Milan	493	279	..	...	...	..	...	32	..	283	..	197	...	356	...
Rome—S. Peter	669	...	..	...	...	..	...	..	..	442	..	396	...	432	...

[a] Has two western towers.
[b] Has two western towers, and a central one.
[c] [1] With spire. Has double aisles round choir.
[d] Has double aisles of equal dimensions, with galleries over them. The south rose window is 45 feet 6 inches in diameter.
[e] Has two western towers.
[f] [2] With spire.
[g] Ladye chapel 62 feet long.
[h] With spires.
[i] Has double aisles continued all round the church.
[k] Exterior dome.

CATHERINE WHEEL, a large ornament in the upper compartment of the windows of Gothic structures; of a circular outline, filled interiorly with a rosette, or radiating divisions, and beautifully variegated.

Catherine-wheel windows are supposed to have been borrowed from our continental neighbours, in the 14th century. In foreign cathedrals, such windows are of enormous magnitude, and of frequent occurrence; as they are commonly met with, not only in the end walls of the transept, as with us, but also in the western façade immediately above the entrance. There is a very fine one in the cathedral of Rheims; and in the great church of St. Oüen, at Rouen, are two; one of which, of great diameter, is called *la rose.* Winchester cathedral has likewise a very large one; but it is still exceeded by one at Cheltenham, in Gloucestershire. In St. Peter's church, Westminster, there is one in each transept.

CATHETUS, a line falling perpendicularly upon another line or surface.

CATHETUS, in architecture, according to Vitruvius, is a right line drawn perpendicularly from the under arris, or line of the sima-inversa at each flank of the Ionic capital, to the centre of the eye of each volute. It must, however, be remarked, that the cathetus drawn in this manner, does not apply to all ancient examples of this order.

CATTLE SHED, or CATTLE HOUSE, in rural economy, an erection for the purpose of containing cattle while feeding, or otherwise. In order to make the feeding of cattle advantageous, it is most important that the cattle sheds should be placed in the most convenient situations with respect to the

fields from which the food is to be brought. In large farms, moveable sheds with temporary yards may be erected according as different fields are in grass or roots, and a great saving of carriage thereby effected, both in the bringing the food to the cattle, and carting the dung unto the land; a clay bottom should be selected, in a high and dry spot, if possible, and it should ever be borne in mind, that, with cattle, as with human beings, cleanliness, free ventilation, and perfect drainage are indispensable to perfect health and a sound condition of the body.

Cattle sheds are most cheaply constructed when placed against walls or other buildings. If they are to be erected in an isolated situation, the expense of the double shed will be much less than that of the single one, to contain the same number of cattle.

Every building of this description should be capable of being well aired, by a free ventilation; and so constructed as to require the least possible labour in giving the food and clearing away the dung; the stalls should be so placed as to keep the cattle dry and clean, with sufficient drains to carry away, and reservoirs to receive the ordure. The greater number of the air-holes should be in the roof; and if the building have gables, there should be a window in each, as high as possible, with moveable boards, or air flights, as in granary windows, which may be easily opened or shut, by means of a small rope. These precautions will not only conduce to the health of the cattle, but tend to preserve the timbers, which, from the alternate wetting by the breath, and drying, would otherwise soon go to decay.

In single sheds, the cattle are, in many parts of the country, fastened to stakes about three feet distant from each other, ranged in a line parallel to the wall, at the distance of about 18 or 20 inches from it, thus leaving sufficient space for laying down the food; but this plan is inconvenient, as it obliges the feeder to pass between the cattle when he feeds them, and is consequently attended with loss of time, and is sometimes dangerous.

The best construction is that which admits a sufficient space for a passage before the cattle, for the feeder to pass along with a wheel-barrow, when he distributes their food. In single sheds, three feet will be sufficient for the width of this passage; and in double sheds, the heads of the cattle should face each other, and the breadth of the passage need not be increased beyond four feet.

Where cattle are fed from the outside, through holes left for the purpose, many inconveniences may arise from wet weather, a severe frost, or a heavy fall of snow; but when fed within, no change of weather can have any influence on their feeding; particularly if due care be taken to keep the provender dry and under cover.

In single sheds, it would be convenient to have a provender-loft above the cattle, for holding, occasionally, hay and straw; a loft of this kind might be provided with flaps in the flooring, furnished with hinges, which, when opened, would afford an easy access for putting in the fodder from the cart, and enable the feeder to throw it into the racks when required. In this case the roof may be supported by posts or pillars, about three or four feet high, on the top of the wall, and eight or ten feet distant from each other; the flaps may be lifted by rings, and be made stationary in any required position, by a catch.

In many places, cows and oxen are bound to stakes, without any stalls, or divisions between them. In some parts, cows are bound in pairs, with a slight division between them; in others, they are not bound, but every cow or ox has a separate stall, divided from the rest by wooden rails, so that they cannot get out, and so narrow that they cannot turn round. Many feeders think the cattle thrive better in stalls of this description, than when they are bound. At each stake there should be a trough for holding provender, and between these two troughs there should be another for water, common to the cattle on both sides; this water-trough, which, as well as the others, may be of stone, and of one piece, may be supplied by a pipe from a cistern or reservoir; and over them should be a perpendicular rack for straw or hay. But though the double stalls, here recommended, are much used for milch cows in different parts of England, they have, in general, only one provender-trough for each cow, and none for water.

In paving stalls for cattle, the declivity is in general too great, which occasions them to stand uneasy. The best mode is similar to that of paving stables. Wood has lately been used with advantage for paving stalls.

In many places, it is the practice to fasten the heads of the cattle between two stakes; by which they can neither lie down in comfort, nor dislodge or destroy those tormenting vermin, which frequently prey upon them. No animal can thrive when confined in this manner.

As the dung of cows and oxen is of a liquid nature, it may perhaps be carried off by means of an iron grating, placed behind each animal, as nearly as can be, in the spot where it usually drops, and immediately over the stall drain, or over a wooden spout, which being continued in a sufficient slope, to a pit or reservoir without, will, with the assistance of water occasionally thrown down, empty itself therein. Should any obstruction occur, the aid of a rake or a hoe, fitted to the drain, may be easily applied; especially if the drain be only covered with a strong plank, which may be taken up when necessary. The greater part of the dung being thus carried away, the remainder will be easily removed. Such a contrivance would save much labour, and facilitate the keeping of cattle clean; it would also be the means of saving a great deal of litter, when scarce or dear. On this part of the subject it may be observed, that the waste of urine and dung, too often seen in even well-conducted farms, is much to be deprecated and lamented—everything of the kind is valuable, and should be conducted to proper reservoirs judiciously constructed and arranged for the purpose, to be afterwards used on the land.

Where a great number of cattle are kept, the erection of sheds or feeding houses on a circular plan, proves very economical, and saves much labour, though a little more expensive in the first cost. In this form of building, the animals stand all round with their tails towards the external wall, leaving a sufficient passage or gangway behind, for them to pass to and from their stalls; proper openings are also to be left in the wall, for discharging the dung, which may fall into covered pits on the outside. The openings should be so contrived, as to be capable of being shut up in severe weather. The area, or space in the middle, is converted to the use of feeding and attendance; and, to render the plan complete, there should be a room above, to store up the different sorts of food that the cattle may require.

The oblong plan likewise admits of much room and convenience, and is a form in which many cattle houses have been lately erected. In this kind of shed, the length of fifty or sixty feet affords room for a great number of cattle. The roof is made shelving, 14 feet in the highest part, and six or seven in the lowest. The place for the reception of the cattle is separated from that wherein the dung is to be deposited, by a wall, or other convenient division, and may be about 18 or 20 feet within, to afford good room. The stalls are twelve feet long, and from 4 feet to 4 feet 6 inches wide; leaving gang ways at the heads and behind the cattle, 3 feet or $3\frac{1}{2}$

feet in breadth. Each stall has two doors, the one for admission of the cattle, the other for the persons who attend them; and when the buildings are of great length, it may be convenient to have additional doors at each end. There should likewise be a water-trough in each stall, and where a stream can be made to run through the whole range, it is productive of great advantage. The boxes, or mangers, for particular sorts of food, as well as racks for hay, are also necessary to render these buildings complete. The bottom of the stalls may be formed of strong planking, laid so as to have a very slight descent, and perforated with holes for the passage of the urine into the reservoir. There should also be openings in the wall, behind the cattle, between every two stalls, of about two feet square, for discharging the dung, with proper shutters fitted to them. Each stall should likewise have a wooden window, of about the same size, for the admission of light and for free ventilation, placed as high as the house or shed will admit. The reservoir for the dung or urine should extend the whole length of the building. For further particulars on this subject, *see* Cow-House.

CAUKING, or Cocking, the mode of fixing the tie-beams of a roof, or the binding-joists of a floor, down to the wall-plates. This was formerly done by dovetailing, in the following manner:—a small part of the depth of the beam at the end of the under side was cut in the form of a dovetail, and a corresponding notch, to receive it, was formed on the upper side of the wall-plate, across its breadth; making, of course, the wide part of the dovetail towards the exterior part of the wall, so that the beams, when laid in their notches, and the roof finished, would tend greatly to prevent the walls from separating, though strained by inward pressure, or even if having a tendency to spread through accidents or bad workmanship. But beams fixed according to this mode, having been found liable to be drawn to a certain degree out of the notches in the wall-plates, from the shrinking of the timber; a more secure mode has succeeded, which prevents all possibility of one being drawn out of the other, however unseasoned the stuff may be, or however affected by changes of weather. *See* Cocking.

CAULICOLES (from *caulis*, a stalk or stem), in the Corinthian capital, eight stalks between each two of the upper row of leaves, ramifying upwards, each into two foliated branches, and seeming to support the volutes under the abacus; each branch supporting one of the sixteen volutes, or helices, two of which are placed at each angle, and two in the middle of each face of the abacus.

CAULKING, in ship-building, the operation of driving a quantity of oakum, or old untwisted ropes, into the seams of the planks in the sides or decks of a ship, to secure the interior from water. After the oakum is driven very hard into the seams, it is covered with hot melted pitch, or rosin, to prevent the water from rotting it.

Caulking Irons, chisels for driving the oakum into the seams; in caulking, these chisels are some broad, some round, and others grooved.

CAUSEWAY, in the most usual sense, denotes a common hard raised way, maintained and repaired with stones and rubbish.

It also signifies a massive construction of stone, stakes, and fascines; or an elevation of fat viscous earth, well beaten; serving either as a road across wet marshy places, or as a mole to retain the waters of a pond, or prevent a river from overflowing low lands.

CAUSTIC CURVE, in the higher geometry, a curve formed by the concourse of the rays of light reflected from some other curve. It is not of much use in building, as this reflection only forms one of the known curves, which are all specified under their respective heads.

CAVÆDIUM (from the Latin, *cava* and *ædium*), a vacant space within the body of a building; in a Roman house, it was what we now call a *court*. According to Vitruvius, there were five kinds of cavædia, denominated *Tuscan*, *Corinthian*, *tetrastyle*, *displuvinated*, and *testudinated*.

The Tuscan cavædium had a roof projecting from each wall, leaving an aperture in the middle; it was suspended on the walls without the intervention of any support from pillars or columns.

The Corinthian cavædium was similar to the Tuscan, except that the roof was supported by columns.

The tetrastyle, as its name implies, had one column at each of the four angles of the roof, for its support.

The displuvinated, being without any roof, admitted a free access of the light to the windows of the surrounding rooms, and was therefore calculated for winter apartments.

The testudinated, which was covered with a vault or concave ceiling, rising from the walls, was used when the span or impetus was not very great; the space above being used for various kinds of apartments. The latter, however, can hardly be deemed a court, though it comes under the general denomination of cavædium.

CAVAZION, Cavasion, or Cavation, an excavation made in the ground for the foundation of a building.

CAVE, a subterraneous hollow place, or the space dug out for cellarage and other purposes below the basement rooms of a house. A common allowance for this is one-sixth of the height of the building. Caves, without doubt, were among the first habitations of men, before they became acquainted with the method of rearing a covering for shelter. They were also used in the early ages as receptacles for the dead.

CAVEA, in the ancient amphitheatres, properly signified the place where the wild beasts were kept; but the word was also applied to the middle part, called the *arena*, and frequently denoted the whole of the interior of the amphitheatres, as well as of the theatres.

CAVETTO (Italian, a diminutive of the Latin, *cavus*, hollow), a concave moulding or cove, the curvature of whose section does not exceed the quarter of a circle; its projection may be equal to its altitude, and should never be less than two-thirds of it. The cavetto, which is the reverse of the ovolo, or quarter-round, is sometimes used in the bed and crowning mouldings of cornices; and forms the upper member of the architrave of some of the most beautiful Grecian Ionics. The hollow moulding used in the bases between the tori, &c., is also called a *cavetto*.

CEILING (from the Latin, *cœlum* the sky, or *celare*, to cover), the inside of the roof, or top of an apartment, opposed to the surface of the floor. Ceilings may be either flat, or coved, or both. Coved ceilings are sometimes concave round the margin and flat in the middle, or otherwise they are vaulted. *See* Vault. The former occupy from one-fifth to one-fourth of the height of the room. The principal sections of vaulted ceilings may be of various segments, equal to, or less than semicircles as may be most suitable to the height of the room.

Flat ceilings are adorned with large compartments, or foliages and other ornaments, or with both.

Compartment ceilings are either formed by raising mouldings on the surface, or by depressing the panels within a moulded enclosure, which may be partly raised upon, and partly recessed within the framing, or entirely recessed. The figures of the panels may be either polygonal, circular, or elliptical. The ceilings of the porticos, and of the interior of

ancient temples, were comparted, and the panels deeply recessed; the prominent parts between them representing, it is said, the ancient manner of framing the beams of wood which composed the floors. The mouldings on the sides of the panels are sunk in one, two, or several degrees, like inverted steps; and the bottoms of panels are most frequently decorated with roses. The figures of these compartments are mostly equilateral and equiangular. Triangles were seldom used; but we find squares, hexagons, and octagons in great abundance. The framing around the panels, in Grecian and Roman examples, is constantly parallel, or of equal breadth; therefore, when squares are introduced, there is no other variety; but hexagons will join in contiguity with one another, or form the interstices into lozenges, or equilateral triangles. Octagons naturally form two varieties, viz., that of its own figure, and squares in the interstices; this kind of compartment is called *coffering*, and the recessed parts *coffers*, which are used not only in plain ceilings, but also in cylindrical vaults.

The borders of the coffering are generally terminated with belts, charged most frequently with foliage; and sometimes, again, the foliage is bordered with guilloches, as in the Temple of Peace, at Rome.

In the ceiling of the entire temple at Balbec, coffers are disposed around the cylindrical vault in one row, rising over each intercolumn, and between every row of coffers is a projecting belt, ornamented with a guilloche, corresponding with two semi-attached columns, in the same vertical plane; one column supporting each springing of the belt.

The ceilings of the ancients were commonly relieved by colour and gilding in various designs, which must have greatly added to the effect of the whole edifice; this practice has been adopted in the new entrance-hall of the British Museum with very great success.

The moderns follow the practice of the ancients in their cupolas and cylindrical vaults, ornamenting them with coffers and belts; and the belts again with frets, guilloches, or foliages. Small panels are ornamented with roses, and large ones with foliage or historical subjects. The grounds may be gilt, and the ornaments white, partly coloured, or streaked with gold; or the ornaments may be gilt, and the grounds white, pearl, straw-colour, light-blue, or any tint that may agree best with the ornaments.

Some ceilings are painted, either wholly or in various compartments only. When a ceiling is painted to represent the sky, it ought to be upon a plane or spheric surface, without being coved at the edges.

Ceilings plane and coved are much employed in modern apartments; they seem to be a kind of medium between the horizontal and the various arched forms practised by the ancients: they do not require so much height as the latter; but they are neither so graceful nor yet so grand.

Vaulted ceilings are more expensive than plane ones; but they are also susceptible of a greater variety of embellishments.

When a ceiling is made on the under side of the rafters of a roof, it is said to be *camp-ceiled*, or *tent-ceiled.*

The timbers of ceilings in Gothic edifices are seldom plastered, although examples are occasionally found, as at Rochester Cathedral, of the Decorated period, which is divided by moulded ribs of wood. The timber ceilings are either flat, concave, circular, or ranging with the principal timbers of the roof; sometimes, however, we have vaulted ceilings of timber, as at Winchester Cathedral. When flat, the ceilings are divided into panels by moulded ribs, which at their intersection are enriched with bosses, pendants, or such like ornaments; sometimes large panels are subdivided by mouldings of a smaller section. The concave ceilings, which present the form of a barrel vault, have most frequently only a single rib running along the top; when others are introduced, it is but sparingly. In all cases, ceilings were enriched with gilding and colours of the most brilliant kind, examples of which are constantly being brought to light during the restoration of old churches.

Plaster was very much used in the ceilings of Elizabeth's time and the succeeding reigns, in which period the ceilings were generally flat, divided into panels by ribs, which, as well as the panels themselves, were often adorned with an exuberance of decoration moulded in the plaster, of which we have many beautiful specimens.

Soffit amounts to nearly the same thing as a *ceiling*, except that the former is applied to the under sides of apertures and cornices, and the latter to a more extended space, as the top or side of an apartment opposite to the floor. The under surface of an arch is also called the *soffit*, or *intrados*, whether it be the head of an aperture, or extended over an apartment.

Arched ceilings are described under the article VAULT.

CEILING, is also understood to be the lath and plaster at the top of a room, or on the under side of common or ceiling joists.

CEILING, in carpentry, the joisting, ribbing, or bracketing for supporting the lath and plaster of the upper surface, or ceiling of a room. There are various kinds of ceilings, as plane ceilings, cove ceilings, and plane and cove ceilings. Under cove ceilings may be classed several other kinds, as waggon-headed, or cylindrical ceilings, dome ceilings, groin ceilings, and spandrel ceilings. For bracketing these different figures, see the words BRACKETING and RIBBING; for the definition of arch ceiling, see VAULT.

CEILING-FLOOR, the joisting and ceiling supported by the beams of the roof.

CEILING-JOISTS, small beams, which are either mortised into the sides of the binding-joists with pulley-mortises, or notched upon, and nailed up to the under sides of the said joists. This last mode takes away from the height of the room; but it is easier to execute, and is thought to be less liable to break the plaster, than when the ends of the ceiling-joists are inserted in pulley-mortises. When girders are introduced in the floor, the under sides of the girders must be furred, to correspond with the level of the under edges of the ceiling-joists.

CELL, in carpentry. *See* SILL.

CELLA, in Roman antiquity, was variously applied. It denoted, in temples, the interior or most retired place, called by the Greeks, *naos;* and in baths, various apartments, as the *frigidaria*, *tepidaria*, *caldaria*, &c. It was also used to denote the apartments of prostitutes, and the bed-chambers of domestics.

CELLA, was likewise applied to monasteries, to denote a lesser one, subordinate to a greater; and was even applied, *vice versa*, to rich monasteries not dependent on any.

CELLAR, in ancient writers, a conservatory for provisions, whether to eat or drink. The term comes from the Latin *celarium*, and is of the same import with *cella*.

CELLAR, as now used, is generally applied to an apartment in which liquors are deposited. Cellars are commonly placed in the lower story of the dwelling-house, sunk beneath the surface of the ground; sometimes they are placed under ground, and are entered from the area before the building; they are sometimes also placed in out-houses. When they are placed within the dwelling-house, or contiguous to an out-building, they should have a north exposure. Cellars should be kept cool, and consequently remote from any place that would communicate heat, and care should be taken to

preserve them of as uniform temperature as possible; for this purpose they should be constructed with double walls and double vaults, leaving a hollow space all round.

Cellars, and other places vaulted under ground, were called by the Greeks *hypogæa*.

CELLARAGE, the number of cellars which a dwelling-house requires, whether one or many.

CELTIC, or Druidical Architecture. A term applied to a class of structures composed of rough unhewn stones of great size, the erection of which is generally attributed to that family of mankind classed under the name of Celts, more especially to the Druids.

These erections are of various descriptions, some consisting of a single stone, others comprising many hundreds; their arrangement also differs very greatly, yet at the same time there is a general similarity which readily marks their relation. The remains are more numerous in this country than in any other, but they are by no means confined to it, similar erections being found not only in the neighbouring islands, in France, Germany, the Netherlands, Portugal, Sweden, and Denmark, but also in Phœnicia, Palestine, India, Malabar, Persia and China, and even in the western continent.

To account for the existence of these works in such remote regions, their construction has been attributed to the Celtæ. These Celts, or Gauls, as they were termed by the Romans, are supposed to be descendants of Gomer, the son of Japhet, whose posterity were called after his name, Gomerians, a title which is identical with the Cimmerians of the Greeks, and the Cimbri of the Latins. That the Celtæ were a branch of the same stock as the Cimmerians, is generally allowed, and it would seem, that they followed in their migrations a south-westerly course, while the Cimmerians pursued a northern, and afterwards a westerly direction. When and where the great family separated is not so universally agreed upon, some writers asserting that they divided before they took their departure from the East, others maintaining that the separation did not take place before they had advanced some distance into Europe. The latter class of writers, who rest mainly on the authority of Herodotus, suppose that the two branches of the one family travelled together until they were overtaken and harassed by the Scythians, when a large number, the Celtæ, moved southward, and spread westward from Asia Minor to Italy, and afterwards to Spain and Britain. It is certain that the Cimmerians were closely followed by the succeeding horde of emigrants, the Scythians, and were by them continually pressed further westwards; it is also generally allowed, that Great Britain was peopled principally by the northern hordes who passed through Denmark and Gaul. If we follow the theory of those who place the separation at the later period on this side the Sea of Azoph, we shall have to account in some other manner for the existence of Celtic remains in Syria and Phœnicia, as well as in India. This difficulty is obviated by attributing the introduction of such a mode of building into this country to the Phœnicians; but then we are left to account for the appearance of the same in the north. The supporters of this opinion quote the statement of Cæsar, that Druidism originated in Britain, and was carried thence to Gaul; and from whom, say they, are the Britons likely to have learned it, but from the Phœnicians, with whom we know they carried on a trade in tin, and who, on account of the advantages obtained from that traffic, were very jealous of their knowledge of the island being extended to other nations; it is allowed, that the structures we are considering were closely allied to Druidism. But this theory, as we said before, raises the difficulty about the existence of similar works in the north, unless it be admitted indeed that the Phœnicians and the northern tribes are of the same family, and if so, we allow its early separation, which is the fact for which the opposite party contend; the only difference being this, that in one case, we need only account for one separation; while in the other, we must necessarily suppose a second. The fact of the identity of the Phœnicians with the northern tribes of the Cimmerians does not rest solely on historic evidence, it is also demonstrable from other facts, such as the common origin of their languages, and the similarity of their customs and religious observances. As far as the former is concerned, there seems to be sufficient evidence to show that the Hebrew, Phœnician, Sanscrit, Irish, and Manx languages, are derived from the same source; and as regards the latter, Dr. Borlase, in his attempt to controvert the opinion, admits that the customs and ceremonies of Asia and of Northern Europe were known and practised by the British Druids, although he maintains that the Britons had several observances which were peculiar to themselves. It would indeed seem that Druidism appeared in a more matured and systematic form in these islands, than elsewhere, and this is but reasonable, for, as was before remarked, the Cimbrians were a nomadic race, and were constantly being driven forward by the Scythians; until, as a last resource, they crossed the German ocean into Britain: here defended on all sides by the sea, they had but little to fear from their aggressors, and were precluded from making further movements westward; here therefore they permanently settled, and betook themselves to the arts of peace, and thus was their religion elaborated and reduced to a system; and as, in the case of Numa, and the early Romans, religion established peace, so in this instance did peace establish and extend religion.

From the above observations, we think, may reasonably be drawn the following conclusions, namely, that the erection of all structures of this kind is to be attributed to one race of people, and their appearance in such different and distant quarters to the fact of that race being migratory or nomadic.

The monuments erected by the Celts may be divided and classed as follows:—Lithoi, composed severally of one, two, and three stones, to the first of which is applied the distinguishing appellation monolithon, and to the last, that of trilithon. They have all the common name of Cromlehs. After these come the kist-vaens, or chests, composed of four stones, and lastly, circles comprising a large number of stones. Further, we have logan, or rocking-stones, tolmen stones, cheese-rings, and cairns.

The most simple of these structures are the monolithoi, or single stones, of which we find a great number in various parts of the British Islands. The first mention of such stones we find, is of that set up by Jacob after his dream, which he named Bethel; the next is that set up by Joshua under an oak by the sanctuary, as a witness unto the Israelites, lest they denied their God. Another stone is spoken of at a later period, called the stone of Abel, upon which the ark was rested; and another, which was placed by Samuel between Mizpeh and Shen as a memorial of the Divine assistance. We read also of the stone Ezel, and the great stone in Gibeon. Many such stones are seen in Palestine at the present day, but not in the places mentioned in the Old Testament. The same kind of stones are almost universal in India, few, if any, of the temples being without them; there are two also in Tyre. It is suggested, that the pillars of Hercules were of this class, and with some probability, as Arrian says, that "Gades was built by the Phœnicians; the sacrifices and ceremonies there performed are all after the Phœnician manner;" and Strabo adds, that there were here two pillars dedicated to Hercules Plato mentions a pillar connected in some way with the

Amazons, and similar lithoi were to be seen at Megara, at Cheronæa, in Thessaly, Ionia and Mauritania, one also within the walls of Athens. Cyrus erected obelisks over the grave o' Abradates, king of Susa, and over those of his wife and officers. Further north we find such stones in Denmark, Sweden, Scotland, Ireland, and in our own country.

As these stones are of necessity much alike in all cases, we need only give a description of one, to afford a general idea of the whole of them; we select that of Rudstone, in the East Riding of Yorkshire. It stands about four yards from the north-east corner of Rudstone Church, and rises above the ground twenty-four feet; if, as is stated, it measures the same below ground, its total length will be forty-eight feet; its breadth is six feet, and thickness two feet; all four sides are slightly convex. The stone is of a very hard quality, and its weight is calculated at above forty tons.

The uses of the monolithoi seem to have been various. That some were used as sepulchral monuments, is allowed by all; and some allow them to have had no other use; such was the pillar set up by Jacob over Rachel's grave, also those erected by Cyrus, as before mentioned. Some were trophies of victories, as that erected by Samuel after his defeat of the Philistines; some were witnesses to covenants, as that set up by Jacob and Laban, and that of Joshua; whilst others are merely boundary stones.

Similar in description are the curious round towers so prevalent in Ireland, which are generally found in the locality of a Christian church, a situation which is accounted for by the supposition that the Christian missionaries were accustomed to rear their edifices near the spot where the pagan temples had stood. It is certain that these towers are very old, as they were considered ancient even in the twelfth century; they vary both in height and construction, but their general appearance is that of a circular obelisk tapering gradually towards the summit, and finishing in a conical roof. *See* Round Towers.

These obelisks are also termed Cromlehs, a word signifying a stone of adoration; also Bothal, which doubtless is the same as the Hebrew, Bethel, both terms signifying the House of God. Under these names are also included monuments of two or three stones, the former comprising an upright pillar with a cross-piece on the top, and the latter two upright stones, with a third at the top, stretching from one to the other; the latter are named likewise trilithons.

Next to the lithoi, or cromlehs, stand the kist-vaens, or monuments of four stones, consisting of three uprights, and one horizontal stone covering the whole: they are often found in, or near circles, and are frequently accompanied with barrows of various kinds. Kist-vaen is a Welsh term, and signifies stone-chest, but the term quoit is frequently applied to the same structures, more especially in Cornwall, and there is one near Cloyne, in Ireland, named Carig-Croith, which is interpreted Sun's House. Such monuments are found in abundance, and in every quarter of the globe; we select one as a specimen, Kit's Coty House, Kent.

This monument stands near to the village of Aylesford, and is thus described by Stowe:—"It consists of four flat stones, one of them standing upright, between two others, inclosing the edges of the first, and the fourth laid flat upon the other three, and is of such height that men may stand on either side the middle stone in time of storm or tempest, safe from wind and rain, being defended with the breadth of the stones, having one at their backs, one on either side, and the fourth over their heads." "About a coit's cast from this monument, lieth another great stone, a great part thereof in the ground, as fallen down where the same had been affixed." This description answers very well to its appearance at the present day, with the exception that the separate stone last mentioned, is now entirely buried in the ground. The dimensions are given as follows in Grose's Antiquities:—"Upright stone on the north or north-west side, eight feet high, eight feet broad, two feet thick; estimated weight, eight tons and a half. Upright stone on the south or south-east side, eight feet high, seven and a half feet broad, two feet thick; estimated weight, eight tons. Upright stone between these, very irregular; medium dimensions, five feet high, five feet broad, fourteen inches thick; estimated weight, about two tons. Upper stone very irregular; eleven feet long, eight feet broad, two feet thick; estimated weight, about ten tons seven hundred-weight."

Monuments of the same description are to be seen in Palestine, the following account of some of which is given by Captains Irby and Mangles:—"On the banks of the Jordan, at the foot of the mountain, we observed some very singular, interesting, and certainly very ancient tombs, composed of great rough stones, resembling what is called Kit's Coty House, in Kent. They are built of two long side-stones, with one at each end, and a small door in front, mostly facing the north; this door was of stone. All were of rough stones, apparently not hewn, but found in flat fragments, many of which are seen about the spot in huge flakes. Over the whole was laid an immense flat piece, projecting both at the sides and ends. What rendered these tombs more remarkable was, that the interior was not long enough for a body, being only five feet. This is occasioned by both the front and back stones being considerably within the ends of the sides only. There are about twenty-seven of these tombs, very irregularly situated." This description would answer very well for our own erections of the kind, were it not for the second stone and doorway, no traces of which are to be found in these islands. Sir Richard Colt Hoare gives two representations of similar stones in Malabar, but he does not accompany them with any description.

Numerous monuments of this kind are to be found throughout the British Isles, but they occur most frequently in Cornwall and Wales, also in the Isle of Anglesea, the last resort of the Druids, and in Ireland.

What the use of these caves were is not agreed upon, some claiming them as sacrificial altars, others as tombs, and others again as simply sacred constructions answering to the ark or sacred chest of the Jews. The former position is maintained by King, who, after referring to the account given by the Romans of the human sacrifices of the Druids, contends for the peculiar applicability of such erections to that purpose; but his opinions do not seem to be borne out by facts. As a decisive argument in the matter, he cites an instance of a structure of the kind existing in the county of Louth, Ireland, which is called the killing-stone; but if this hold good as a proof, a similar one may be advanced for the second class of opinions, in the case of the Trevethy Stone in Cornwall, the word Trevedi signifying, in the British language, it is said, the Place of Graves; and besides this, Kit's Coty House is transferred into Catigern's house of coits, the term coit being translated large flat stone. This place is so named, it is averred, from the fact of Catigern being buried there, after the battle with Hengist and Horsa, which occurred at Aylesford, and in which he was slain.

We have now arrived at the largest and most interesting class of monuments, the Druidical circles; they consist of one or more circles of upright stones placed at short intervals from each other; the circles are usually concentric, but we have not unfrequently two smaller circles placed side by side within a larger one, and the whole surrounded with a circular ditch and vallum. The stones composing the cir

cles are not always single, but sometimes consist of trilithons, sometimes of kist-vaens. Such erections are found in various localities, although more frequently in this country than elsewhere. Mention is made of them in the Sacred writings in more than one instance: Moses is said to have erected an altar, and twelve pillars, according to the twelve tribes of Israel, ere he ascended the mount to receive the law; he also gives directions to the Israelites at a later period, that upon crossing Jordan they should set up in mount Ebal great stones, and plaster them with plaster, and especially orders that they should be whole stones, and unwrought; we accordingly find Joshua setting up twelve stones in the midst of Jordan, and taking twelve further forward, and pitching them in Gilgal, as a memorial of the passage of the Jordan;—it is worthy of remark, that the word Gilgal signifies a wheel or circle, and doubtless the place was so named from the circle of stones there set up. Such circles are found likewise in Sweden, Norway, Denmark, and Iceland, in which last place they are termed Doom circles; they are spoken of by Clarke as existing in the Troad, and Sir William Ouseley gives views and description of one to be seen in Persia; but what is most remarkable, there exist three in America, one upon a high rock on the bank of the river Winnipigon.

Such structures were unquestionably temples in which the Druidical services were performed, and not only so, but they seem to have been the prototype of all heathen temples, for we gather from authentic sources, that the most ancient heathen fanes were all open to the sky without roof of any kind. It is argued by some, that they were used merely for civil purposes, or that some of them at least were exclusively so employed; that they were all so employed we do not for a moment doubt, but we contend that they were all likewise employed for sacred purposes; indeed, the government of the people was so implicit with their religion, that the Druids were at one and the same time both priests and rulers.

The circles are supposed by some to have been closely connected with astrology, and indeed the agreement of the number and arrangement of the stones with the divisions of the ancient cycles is remarkable, as will be seen by referring to the tables of Dr. Stukeley, which are given in the following page.

The most remarkable of the circular erections in Great Britain are those of Stonehenge and Abury, both of which are situate in the neighbourhood of Salisbury Plain. The former, about seven miles north of Salisbury, is approached by a broad avenue protected on either side by a vallum, or long mound of earth; this avenue leads into a large circular platform three hundred feet in diameter, enclosed from the surrounding plain by means of a vallum fifteen feet in height, with a ditch on either side of it, and, as some suppose, by an inner circle of stones, some few having been found in immediate proximity to the other circle. In the avenue, at a distance of about a hundred feet from the circular ditch, is a large stone inclining towards you as you approach, and a similar one in the ditch at the entrance. Passing onwards in a straight direction you approach a large number of stones composing the temple, more especially so termed, which consists of an outer circle of stones fourteen feet in height, seventeen of which still remain, six scattered in various parts of the circle, but eleven on the north-east side, at equal distances from each other, forming a continuous segment of a circle, thus demonstrating the form and position of the whole. This circle consisted originally of thirty stones, surmounted by a continuous impost of large flat stones, which were fitted on to the uprights by mortise and tenon, and formed a complete and regular circle. Within this enclosure is another of a similar figure, and eighty-three feet in diameter, composed of the same number of stones, which however are of smaller dimensions and without imposts. Within this again were five separate structures, termed trilithons, each consisting of two large stones surmounted with an impost, and having three smaller stones a short distance in advance. These structures were situate, one immediately opposite the avenue, and two on each side of it, leaving an unoccupied space for an entrance. The larger upright stones were more lofty than any of the others, one of them measuring upwards of twenty-one and a half feet in height; thus overtopping all the outer circles. In front of the central trilithon, is placed, by Stukeley, a low flat stone, supposed to be the altar. The avenue noticed at the commencement of this description is continued in a north easterly direction for a distance of about a third of a mile, where it separates into two branches, the one leading southward between two rows of barrows, the other in the opposite direction for more than a mile and a half to a spot called the cursus, which is a flat tract of land, bounded on each side by banks and ditches, and at its extremities by barrows or tumuli.

The erection at Abury, although of more rude construction than Stonehenge, is of more stupendous dimensions; few of the stones remain at the present day, great numbers having been employed in the erection of the neighbouring town, yet we have accounts of many which existed at a previous period, with the aid of which, and of his own experienced judgment, Dr. Stukeley made out a plan of the original structure entire. It consisted of a large circular enclosure of more than twenty-eight acres, surrounded with a great vallum and ditch, the inner slope of the former measuring eighty feet, its circumference at the apex being four thousand four hundred and forty-two feet. On the inner side of the ditch, and close upon its bank, was a circle thirteen hundred feet in diameter, composed of one hundred immense stones of an average height of seventeen feet, and placed at a distance of about twenty-seven feet from each other. Within this outer circle were two smaller ones, situate side by side on a diameter running from north-west to south-east, of the more northerly of which some stones of great size are still standing. These circles consist of two concentric rows of stone, within which, in the southern circle, was a central obelisk, towards which, it is said, the worshippers used to turn during the celebration of the rites, and in the same position, on the northern circle, a structure termed a cove, consisting of three large stones placed towards each other at an obtuse angle. The distance of the centres of the north and south circles is given at five hundred and eighteen feet, and the distances of their circumferences at eighty-six feet, thus determining the length of the diameters, four hundred and thirty-two feet. These admeasurements, however, must be received with some reserve, as the remains were so scanty at the time they were taken, as to leave the exact position of the circles or their centres a matter of great uncertainty. Of this structure, which it is calculated could originally boast in all of more than six hundred stones, but few portions remain, the rest having been employed either in the erection of the town of the same name, which stands within its boundaries, or in constructing and repairing its roads.

From two entrances on the southern side of the exterior circle, extend two avenues, each formed by a double line of upright stones, and of more than a mile in length. One of them running in a south-easterly direction, the breadth of which averages fifty feet, led to an elliptical piece of ground on the top of a hill called the Hackpen, enclosed within two

hundred upright stones, and surrounded on all sides with barrows. The south-western avenue, consisting of about two hundred stones, is nearly a mile and a half in length, and terminates in a single stone. It has to be remarked, that both these avenues run in a curved direction, and are hence by some supposed to represent a serpent, thus connecting the religion of the Druids with the early and prevalent superstition of serpent-worship; the western avenue answers to the tail of the reptile; the larger circle to the body; while the head is represented by the Hackpen, a word which, in some languages, signifies *serpent*. The circles of this portion of the structure are concentric, the outer one containing forty stones, having a diameter of one hundred and fifty feet, and the inner, which is composed of eighteen stones, a diameter of forty-eight feet.

Between the two avenues just mentioned, are three mounds, or hills, one of which, situate at the extreme south, and nearly midway between the extremities of the avenues, is remarkable as being the largest artificial mound in Europe; it is named Silbury Hill. The base of this mound covers a space of five acres and thirty-four perches, and its circumference is two thousand and twenty-seven feet, the length of the slope three hundred and sixteen feet, and the diameter of the platform, at its apex, one hundred and twenty feet. Besides this and other erections connected with Abury, are a variety of Druidical remains scattered in all directions for some distance round the great circle.

The number of stones employed at Abury and Stonehenge, with their distribution, as given by Dr. Stukeley :—

ABURY.	Stones.
The great circle contains	100
North temple, outer circle	30
North temple, inner circle	12
South temple, outer circle	30
South temple, inner circle	12
The cove and altar	4
Obelisk and altar	2
The eastern avenue	200
The western avenue	200
Hackpen, outer circle	40
Hackpen, inner circle	18
Long stone-cove jambs	1
The Ring stone	1
Closing stone of tail	1
Total	652

STONEHENGE.	Stones.
The great-circle uprights	30
The great-circle imposts	30
Inner circle	40
Trilithon uprights	10
Trilithon imposts	5
Inmost stones	19
Altar	1
Stones within the vallum	2
Large table stone	1
Distant pillar	1
Stone at entrance	1
Total	140

Mr. Toland gives the following account of a remarkable structure of this kind. "In the isle of Lewis," he says, "at the village of Classerniss, there is one of these temples very remarkable. The circle consists of twelve obelisks, about seven feet high each, and distant from each other six feet. In the centre stands a stone thirteen feet high, in the perfect shape of the rudder of a ship. Directly south from the circle, there stand four obelisks running out in a line; as also another such line due east, and a third to the west, the number and distances of the stones being in these wings the same; so that this temple, the most entire that can be, is at the same time both round and winged. But to the north, there reach, by way of avenue, two straight ranges of obelisks, of the same bigness and distances with those of the circle; yet the ranges themselves are eight feet distant, and each consisting of nineteen stones, the thirty-ninth being the entrance to the avenue." Dr. Borlase mentions three circles of stone in the parish of St. Clare, Cornwall, called the Hurlers, which are separate and distinct from each other, but whose centres are in one straight line.

Amongst some few of the most important circles besides those already mentioned, may be classed that of Stanton Drew, consisting originally of three circles, of the larger of which five stones remain, and of the smaller, a larger number; the stones are much inferior in point of size to those already described. Rollrich is another circle of stones near Chipping Norton, Oxfordshire, the highest of which is not more than five feet above the ground; they are irregular, and of unequal height. Another is found near Penrith, Cumberland, which consists of seventy-seven stones, each ten feet in height, and before them, at the entrance, stands a single one by itself, fifteen feet high. Similar structures are found in other parts of England, Scotland, and the Isles, but none of them approaching in size those of Abury or Stonehenge.

There exists at Carnac, in Brittany, a monument, which in size approaches nearer to Abury than any other such work, but which, in its form and general character, is perfectly unique; it is of ruder formation than either Abury or Stonehenge, "and consists of eleven rows of unwrought pieces of rock or stone, merely set up on end in the earth, without any pieces crossing them at top. These stones are of great thickness, but not exceeding nine or twelve feet in height; there may be some few fifteen feet. The rows are placed from fifteen to eighteen paces from each other, extending in length—taking rather a semicircular direction—above half a mile, on unequal ground, and towards one end upon a hilly site. When the length of these rows is considered, there must have been nearly three hundred stones in each, and there are eleven rows; this will give some idea of the immensity of the work, and the labour such a construction required. It is said that there are above four thousand stones still remaining." This account is taken from Mrs. Stoddart's Tour in Normandy and Brittany; but a French writer gives the size of some of the stones at twenty-one and twenty-two feet, and he especially alludes to one specimen, which was twenty-two feet high, twelve broad, and six deep; its weight is given at two hundred and fifty-seven thousand pounds.

Logan stones, or rocking-stones, as they are less technically termed, are stones, often of an immense size, poised on others, or on natural rocks, in such a peculiar manner, as to move with the slightest touch. They seem to have been erected at various times and places. They were known to the Greeks, and called by them *λιθοι εμψυχοι*, or live stones, also named Petræ Ambrosiæ, from the ceremony they underwent of being anointed with oil. Pliny takes notice of one erected by Lycippus, at Tarentum, and also of one at Cyzicum, which is said to have been left by the Argonauts; but the most celebrated was the Gygonean stone, near the Pillars of Hercules, of which Ptolemy Hephæstion relates, that it stands near the ocean, and may be moved with the stalk of an asphodel, but cannot be removed by any force. Pliny likewise says of one at Harpava, in Asia, that it is of so strange and wonderful a nature, that if even a finger is laid on it, it will move, but if you thrust it with your whole body, it will not move at all.

These stones are very common in Britain; there are several in Cornwall and Yorkshire, as also in Scotland, where they are called Claca Breath, or stones of judgment; it is known that there existed formerly several in the island of Iona, which have since been destroyed. In some cases the stone rests on two points, in others on one; it is said that the junction was formed in one instance in Scotland, where the stone had been removed, by a protuberant knob in the upper stone fitting into a socket.

A stone of this nature is that near Penzance, Cornwall, named Men-amber; it is eleven feet in length, four feet in depth, and six in width. Its equilibrium was destroyed by Cromwell's soldiers, by breaking off a portion. Another

logan stone situate at Land's End, is said to weigh seventy tons; it stands on one of a stupendous group of granite rocks which rise to a prodigious altitude, and overhang the sea; it was thrown down by a ship's crew, but the good sense of the inhabitants obliged them to replace it.

Borlase was the first to notice a structure of a somewhat different character to the last, called Tolmen, or Hole of Stone, consisting of a large stone supported at two points by others, leaving a space between them, through which it is supposed devotees passed for religious purposes. Of a similar opening at the extremity of Malabar Hill, in the island of Bombay, a writer says—"This place is used by the Gentoos as a purification for their sins, which they say is effected by their going in at the opening below, and emerging out of the cavity above." We find stones of this kind in Cornwall and in Ireland; the most noted is that in the parish of Constantine, Cornwall, which is thus described by Dr. Borlase:—"It is one vast egg-like stone, placed on the points of two natural rocks, so that a man may creep under the great one, and between its supporters, through a passage about three feet wide, and as much high. The longest diameter of this stone is thirty-three feet, the depth thirteen feet, and the breadth eighteen feet six inches. I measured one half of the circumference, and found it, according to my computation, forty-eight feet and a half, so that this stone is ninety-seven feet in circumference, about sixty feet across the middle, and by the best information I can get, contains at least seven hundred and fifty tons of stone. Getting up a ladder to view the top of it, we found the whole surface worked like an imperfect or mutilated honey-comb, into basons; one much larger than the rest was at the south end, about seven feet long; another at the north, about five; the rest smaller, seldom more than one foot, often not so much: the sides and shape irregular. Most of these basons discharge into the two principal ones (which lie in the middle of the surface) those only excepted which are near the brim of the stone, and they have little lips or channels which discharge the water they collect over the sides of the Tolmen; and the flat rocks which lie underneath, receive the droppings in basons cut into their surfaces. This stone is no less wonderful for its position than for its size, for although the under part is nearly semicircular, yet it rests on the two large rocks, and so slight and detached does it stand, that it touches the two under stones, but as it were on their points.

Wring-cheeses, so named from their resemblance in form to an ancient cheese-press, consist of large masses of stone placed one upon the other for several tiers, the whole resting on a base of much smaller dimensions than the superincumbent mass. By some it is contended that they are merely the productions of nature, but it seems more reasonable to suppose, that at least some art has been employed in their formation. They are by some termed rock-idols, under the supposition that they were worshipped as gods.

One such monument, situate in the parish of St. Clare, Cornwall, Dr. Borlase thus describes:—"The rock now called Wring-cheese, is a group of rocks that attracts the admiration of all travellers. On the top stone of this, were two regular basons; part of one of which has been broken off. The upper stone was, as I am informed, a logan or rocking-stone, and might, when it was entire, be easily moved with a pole, but now great part of that weight which kept it on poise, is taken away. The whole heap of stones is thirty-two feet high, the great weight of the upper part and the slenderness of the under part make every one wonder how such an ill-grounded pile could resist, for so many ages, the storms of such an exposed situation." Mr. Hayman Rooke mentions one situate on Brimham Craggs, Yorkshire, the circumference of which is forty-six feet, and the pedestal on which it rests, only one foot by two feet seven inches.

Cairns are conical heaps of loose stones frequently found on the top of hills or artificial tumuli; the term is derived by Mr. Roland from two Hebrew words, signifying coped heaps. On these are supposed to have been kindled fires, at which certain religious ceremonies took place, such as that mentioned as being observed by the Israelites in making their children pass through the fire, in imitation of their heathen neighbours; thus connecting the customs of the British Druids with those of Asia and Phœnicia. From these Druidical practices may have arisen perchance the ordeal by fire of later times.

At New Grange, near Drogheda, Ireland, is a curious sepulchral pyramid of stone, formed of pebble stones, the weight of the solid contents of which amounted to no less than one hundred and eighty-nine thousand tons. The plan of this monument is curvilinear, and covers about two acres of ground, and is surrounded by a number of large unhewn stones, rising about seven feet above the ground; the height of the pyramid is calculated at seventy feet. A great number of stones, removed for paving and other purposes, led to the discovery of a passage leading into an interior vaulted apartment. This passage began about forty feet within the body of the work, and is entirely composed of large flag stones; its length is sixty-one feet, the width three feet, and the height varies from two to nine feet. This passage leads into an octangular vaulted apartment, whose diameter is seventeen feet, and its height twenty; the vault or dome is remarkable as being composed of overlapping horizontal stones, the upper ones projecting inwardly beyond the lower, sustained in their position by having a larger portion of each stone upon the one beneath it, than projects towards the interior; this construction is exactly similar to that of the tomb of Agamemnon, or treasury of Atreus at Mycene. The side of this irregular octagon immediately opposite the entrance, is formed into a niche, as are also two sides at the right and left, similar to the erections called kist-vaens, the last two containing each a rock-bason. This building is, we believe, the only one of its kind existing in Britain.

We have not included the barrows or tumuli in the list of monuments to be considered, simply because they can scarcely be considered to have any great connection with Architecture, but as they are closely allied to the structures we have been considering, we ought not to pass them by without notice. They are mere mounds of earth, of various shapes, raised, as is supposed, over the graves of men of rank, and are found in great numbers in the neighbourhood of the larger monuments: some of them are of oblong shape, raised like coped tombs, some triangular, some circular and oval, of which again some are convex, some concave. Some are of the shape of bowls, and some of bells, while others are of a conical form; occasionally two are formed together, and are called twin-barrows, but more frequently they are seen separate. Many of them have been opened, and are found to contain not only human remains, but also spear-heads and other implements of war, besides articles of domestic use, such as earthen vessels and the like. Their contents determine as well their use, as the date of their formation.

CEMENT. The word cement may be defined as any glutinous or other substance, capable of uniting bodies in close cohesion, or making them adhere firmly together, so as to form of the whole one solid mass—as mortar, glue, solder, asphaltum, &c. Cements are of various kinds, but, for convenience, may be divided into NATURAL and ARTIFICIAL.

Natural cements are found in Russia, France, and other countries, and indeed the substance so extensively used in England, and very improperly termed Roman cement, is nothing more than a natural cement, resulting from a slight calcination of a calcareous mineral, containing about 31 per cent of ochreous clay, and a few hundredths of carbonate of magnesia and manganese. It may be observed, that when the proportion of clay in calcareous minerals exceeds 27 to 30 per cent, it is seldom converted into lime by calcination, but they then furnish a kind of natural cement, which can be used by pulverizing it, and kneading it with water.

There are some natural cements which do not set in water for many days, but these are now rarely used; those which solidify quickly, being generally preferred. The adhesive power of some cements in the open air, is very remarkable; and we have ourselves seen 33 bricks stuck to one another by Roman cement, and projecting at right angles from the side of a wall.

The argillaceous limestones, and the artificial mixtures of pure lime and clay, in the proportions requisite to constitute hydraulic lime by the ordinary calcination, become natural or artificial cements, when they have been subjected merely to a simple incandescence, kept up for some minutes.

Calcareous cements may be classed according to the three following divisions, namely, *simple calcareous cements*, *water cements*, *maltha*, and *mastics*.

1st, Simple calcareous cements include those kinds of mortar which are employed in land-building, and consist of lime, sand, and fresh water.

Calcareous earths are converted into quick-lime by burning, which being wetted with water falls into an impalpable powder, with great extrication of heat: and if in this state it is beat with sand and water, the mass will concrete and become a stony substance, which will be more or less perfect according to its treatment, or to the quality and quantities of ingredients.

When carbonated lime has been thoroughly burned, it is deprived of its water, and all, or nearly all, of its carbonic acid; much of the water, during the process of calcination, being carried off in the form of steam.

Lime-stone loses about $\frac{4}{9}$ of its weight by burning, and when fully burned, falls freely, and will produce something more than double the quantity of powder, or slacked lime, in measure, that the burnt lime-stone consisted of.

Quick-lime, by being exposed to the air, absorbs carbonic acid with greater or less rapidity, as its texture is less or more hard; and this, by continued exposure, becomes unfit for the composition of mortar; hence it is that quick-lime made of chalk, cannot be kept for the same length of time between the burning and slacking, as that made from stone.

Marble, chalk, and limestone, with respect to their use in cements, may be divided into two kinds—simple lime-stone, or pure carbonate of lime, and argillo-ferruginous lime, which contains from $\frac{1}{20}$ to $\frac{1}{12}$ of clay, and oxide of iron, previous to calcination: there are no external marks by which these can be distinguished from each other, but whatever may have been the colour in the crude state, the former, when calcined, becomes white, and the latter more or less of an ochrey tinge. The white kinds are more abundant, and when made into mortar will admit of a greater portion of sand than the brown, consequently are more generally employed in the composition of mortar; but the brown lime is by far the best for all kinds of cement. If white, brown, and shell lime, recently slacked, be separately beat up with a little water into a stiff paste, it will be found that the white lime, whether made from chalk, lime-stone, or marble, will not acquire any degree of hardness; the brown lime will become considerably indurated; and the shell lime will be concreted into a firm cement, which, though it will fall to pieces in water, is well qualified for interior finishings, where it can be kept dry.

It was the opinion of the ancients, and is still received among our modern builders, that the hardest lime-stone furnishes the best lime for mortar; but the experiments of Dr. Higgins and Mr. Smeaton have proved this to be a mistake, and that the softest chalk lime, if thoroughly burned, is equally durable with the hardest stone lime, or even marble: but though stone and chalk lime are equally good under this condition, there is a very important practical difference between them; as the chalk lime absorbs carbonic acid with much greater avidity; and if it be only partially calcined, will, on the application of water, fall into a coarse powder, which stone lime will not do.

For making mortar, the lime should be immediately used from the kiln; and in slacking it, no more water should be allowed than what is just sufficient: and for this purpose Dr. Higgins recommends lime-water.

The sand made use of should be perfectly clean; if there is any mixture of clay or mud, it should be divested of either, or both, by washing it in running water. Mr. Smeaton has fully shown by experiments, that mortar, though of the best quality, when mixed with a small proportion of unburnt clay, never acquires that hardness, which, without this addition, it speedily would have attained. If sea-sand be used, it requires to be well washed with fresh water, to dissolve the salt with which it is mixed, otherwise the cement into which it enters, never becomes thoroughly dry and hard. The sharper and coarser the sand is, the stronger is the mortar; also a less proportion of lime is necessary. It is therefore more profitable to use the largest proportion of sand, as this ingredient is the cheapest in the composition.

The best proportion of lime and sand in the composition of mortar is yet a desideratum.

It may be affirmed, in general, that no more lime is required to a given quantity of sand, than what is just sufficient to surround the particles, or to use the least lime, so as to preserve the necessary degree of plasticity. Mortar in which sand predominates, requires less water in preparing, and therefore sets sooner: it is harder, and less liable to crack in drying; for this reason, that lime shrinks greatly in drying, while sand retains its original magnitude. We are informed by Vitruvius, lib. ii., chap. v., that the Roman builders allowed three parts of pit sand, or two of river or sea sand, to one of lime; but Pliny, *Hist. Nat.* lib. xxxvi., prescribes four parts of coarse sharp pit sand, and only one of lime. The general proportion given by our London builders, is $1\frac{1}{2}$ cwt., or thirty seven bushels of lime, and $2\frac{1}{2}$ loads of sand; but if proper care were taken in the burning of the lime, the quality of the sand, and in tempering the materials, a much greater quantity of sand might be admitted.

Mr. Smeaton observes, that there is scarcely any mortar but which, if the lime be well burned, and the composition well beaten in the making, will require two measures of sand to one of unslacked lime; and it is singular, that the more the mortar is wrought or beat, a greater proportion of sand may be admitted. He found that by good beating, the same quantity of lime would take in one measure of terras, and three of clean sand, which seems to be the greatest useful proportion.

Dr. Higgins found that a certain proportion of coarse and fine sand improved the composition of mortar; the best proportion of ingredients, according to experiments made

by him, is as follows, by measure: Lime, newly slacked, one part; fine sand, three parts; coarse sand, four parts. He also found that an addition of one-fourth part of the quantity of lime, of burnt bone-ashes, improved the mortar, by giving it tenacity, and rendering it less liable to crack in drying.

The mortar should be made under ground, then covered up, and kept there for a considerable length of time, the longer the better; and when it is to be used, it should be beat up afresh. This makes it set sooner, renders it less liable to crack, and harder when dry.

The stony consistence which it acquires in drying, is owing to the absorption of carbonic acid, and a combination of part of the water with the lime: and hence it is that lime that has been long kept after burning is unfit for the purpose of mortar, for in the course of keeping, so much carbonic acid has been imbibed as to have little better effect, in a composition of sand and water, than chalk or lime-stone reduced to a powder from the crude state, would have in place of it.

Grout is a cement, containing a larger proportion of water than is employed in common mortar, so as to make it sufficiently fluid to penetrate the narrow irregular interstices of rough stone walls. Grout should be made of mortar that has been long kept and thoroughly beat, as it will then concrete in the space of a day: whereas, if this precaution be neglected, it will be a long time before it sets, and may even refuse setting for ever. *See* GROUT.

Mortar made of pure lime, sand, and water, may be employed in the linings of reservoirs and aqueducts, provided it have sufficient time to dry; but if the water be put in while it is wet, it will fall to pieces in a short time; and, consequently, if the circumstances of the building be such as render it impracticable to keep out the water, it should not be used: there are, however, certain ingredients put into common mortar, by which it is made to set immediately under water, or if the quick-lime contain in itself a certain portion of burnt clay, it will possess this property.

From the friable and crumbling nature of our mortar, a notion has been entertained by many persons, that the ancients possessed a process in its fabrication, which has been lost at the present day; but the experiments of Mr. Smeaton, Dr. Higgins, and others, have shown this notion to be unfounded, and that nothing more is wanting than that the chalk, lime-stone, or marble, be well burned, and thoroughly slacked immediately, and to mix it up with a certain proportion of clean large-grain sharp sand, and as small a quantity of water as will be sufficient for working it; to keep it a considerable time from the external air, and to beat it over again before it is used: the cement thus made will be sufficiently hard.

The practice of our modern builders, is to spare their labour, and to increase the quantity of materials they produce, without any regard to its goodness: the badness of our modern mortar is to be attributed both to the faulty nature of the materials, and to the slovenly and hasty methods of using it. This is remarkably instanced in London, where the lime employed is chalk lime, indifferently burnt, conveyed from Essex or Kent, a distance of ten or twenty miles, then kept many days without any precaution to prevent the access of external air. Now, in the course of this time it has absorbed so much carbonic acid as nearly to lose its cementing properties, and though chalk lime is equally good with the hardest lime-stone, when thoroughly burned, yet, by this treatment, when it is slacked, it falls into a thin powder, and the core or unburned lumps are ground down, and mixed up in the mortar, and not rejected, as it ought to be.

The sand is equally defective, consisting of small globular grains, containing a large proportion of clay, which prevents it from drying, and attaining the necessary degree of hardness. These materials being compounded in the most hasty manner, and beat up with water in this imperfect state, cannot fail of producing a crumbling and bad mortar; and to complete the miserable composition, screened rubbish, and the scraping of roads, are thrown in, as substitutes for pure sand.

How very different was the practice of the Romans! The lime which they employed was perfectly burnt, the sand sharp, clean, and large-grained; when these ingredients were mixed in due proportion, with a small quantity of water, the mass was put into a wooden mortar, and beaten with a heavy wooden or iron pestle, till the composition adhered to the mortar: being thus far prepared, they kept it till it was at least three years old. The beating of mortar is of the utmost consequence to its durability, and it would appear that the effect produced by it, is owing to something more than a mere mechanical mixture. *See* MORTAR.

Water cements are such as are impervious to water: they are generally made of common mortar, or of pure lime and water, with the addition of some other ingredient to give it the property of hardening under water.

For this purpose there are several kinds of ingredients, as puzzolana, cellular basalt, or wakke, compact basalt, coal-ashes, coal-cinders, wood-ashes, pumice-stone, brick-dust, powder of quick-lime, forge-scales, roasted iron-ore, &c.

The cement employed by Mr. Smeaton, in the construction of the Eddystone lighthouse, was composed of equal parts, by measure, of slacked Aberthaw lime and puzzolana; this proportion was thought advisable, as the building was exposed to the utmost violence of the sea: but for other aquatic works, as locks, basins, canals, &c., a composition made of lime, puzzolana, sand, and water, in the following proportion, viz., two bushels of slacked Aberthaw lime, one bushel of puzzolana, and three of clean sand, has been found very effectual. It is well known, that sand and lime, mixed together with care, will incorporate and form a mortar impervious to water, and sufficient even for the linings of cisterns and reservoirs; but then the mortar must be hardened before it is exposed to the water, or otherwise it will crumble to pieces; and therefore, if the situation be such as to require the mortar to be dried in a certain time, the use of this cement must be abandoned.

Among the ancient nations, the Romans appear to have been the only people who practised building in water to any great extent, particularly in the sea. The discovery of puzzolana is attributed to the following circumstance, among this great people. The Bay of Baiæ, like our fashionable watering-places, was the summer resort of all the wealthy in Rome: the inhabitants of this place did not content themselves with erecting their houses as near the shore as possible, but they even constructed moles and small islands, on which they erected their summer-houses in the more sheltered parts of the bay. By the fortunate discovery of an earthy substance at the neighbouring town of Puteoli, they were enabled to build both expeditiously and securely in water. From this circumstance, the earth thus discovered was called *pulvis Puteolanus*, "powder of Puteoli," "Puteolean powder," or, as it is now denominated, *puzzolana*, which is a mineral of a light porous, friable nature, and of a red colour, supposed to be formed by concretion of the volcanic ashes of Vesuvius, near to which mountain the town of Puteoli is situated. The original material seems to be a ferruginous clay, which, baked and calcined by the force of volcanic fire, and mixed with common mortar, not only enables it to acquire a remark

able hardness in the air, but to become as firm as stone under water. The only preparation which puzzolana undergoes, is that of pounding and sifting, by which it is reduced to a coarse powder; in this state it is beaten up with lime, either with or without sand, which forms a mass of remarkable tenacity, that sets under water with great celerity, and at last acquires a strength and hardness equal to those of free-stone.

Among the nations of modern Europe, none have practised the art of building under water to so great an extent as the Dutch, to whom we are indebted for the discovery of another valuable material, admirably adapted for aquatic works: this substance is called *terras*, or *trass*, and is nothing more than *wakke*, or cellular basalt. It is procured chiefly from Bockenheim, Frankfort on the Maine, and Andernach, whence it is transported down the Rhine, in large quantities, to Holland, and is prepared by grinding and sifting, so as to reduce it to the consistence of coarse sand; when it is mixed, in the following manner, with blue argillaceous lime from the banks of the Scheldt. They take such a quantity of quick-lime as may be judged sufficient for a week, and spread it in a kind of bason, in a stratum about a foot thick, and sprinkle it with water; this is covered with a stratum of terras, of about the same thickness, and thus left for two or three days; it is then beaten into a mixture, and left for two days longer; after which such portions as are wanted for daily consumption are taken from the mass, and beaten up again previous to being used.—This is the celebrated terras mortar, with which the mounds and other aquatic works, used as a defence for protecting the low lands of Holland, against the incursions of the sea, are consolidated.

The proportion of the ingredients for terras mortar, as used in Britain in the construction of our water-works, is the same as practised by the Dutch, viz., one measure of quick-lime and two of slacked, in the dry powder, mixed with one measure of terras, and well beaten together to the consistence of a paste, using as little water as possible.

Another kind, almost equally good, and considerably cheaper, is composed of two measures of slacked lime, one of terras, and three of coarse sand; but this composition requires more labour in beating than the foregoing, and produces three measures and a half of excellent mortar. When the building is composed of rough stones, which leave irregular interstices and large cavities, the joints may be filled with pebble mortar, which is thus composed: Take two measures of slacked argillaceous lime, half a measure of terras, or puzzolana, one of coarse sand, one of fine sand, and four of small pebbles screened and washed, and mix them together. Pebble mortar was a favourite cement among the Romans, and has been used, ever since their time, in those works wherein a large quantity of mortar is required.

Terras mortar will only acquire its proper hardness under water; for if permitted to dry by exposure to the air, it never arrives at the same degree of hardness as if the same lime had been mixed with good clean common sand, and is very friable and crumbling; but when kept always wet, it throws out a substance something like the concretion in lime-stone caverns, called *stalactite*, which substance acquires a considerable hardness, and in time becomes so exuberant as to deform the face of the walls.

Although the Dutch terras has hitherto been prepared with cellular basalt, it appears, from the experiments of Morveau, that the common compact basalt, if previously calcined, will answer nearly the same purpose. Compact basalt abounds in all the districts where coal is raised, and may therefore be procured easily, and calcined with the refuse coal.

In some parts of the Low Countries, coal-ashes are substituted for terras with very good effect, of which the valuable *cendrée de Tournay* is a striking instance. The deep blue argillo-ferruginous lime-stone of the Scheldt is burnt in kilns, with a slaty kind of pit-coal found in the neighbourhood. When the calcination of the lime is completed, the pieces are taken out, and a considerable quantity of dust and small fragments remain at the bottom of the kiln. This refuse, consisting of coal-ash, mixed with about one-fourth of lime-dust, is called the *cendrée*, and is thus made into mortar with lime: Put a bushel of the materials into any suitable vessel, and sprinkle it with as much water as is sufficient to slack the lime; then take another bushel, and treat it in the same manner; and so on, till the vessel is filled. In this state it remains some weeks, and may be kept for a much longer time, if covered with moist earth. A strong open trough, containing about two cubic feet, is filled about two-thirds with cement in the above state, and by means of a heavy iron pestle, suspended at the end of an elastic pole, is well beaten for about half an hour; at the end of this time it becomes of the consistence of soft mortar, and is then laid in the shade from three to six days, according to the dryness of the air. When sufficiently dry, it is beaten again for half an hour, as before; and the oftener it is beaten, the better will be the cement; three or four hours, however, are sufficient to reduce it to the consistence of a uniform smooth paste. After this period it becomes too stiff, on account of the evaporation of its water, as no more of this fluid is allowed to enter the composition than what was at first employed to slack the lime. The cement, thus prepared, is found in a few minutes to unite so firmly, upon brick or stone, that still water may be let in immediately upon the work, without any inconvenience; and by keeping it dry for twenty-four hours, it has nothing farther to fear from the most rapid current.

A composition of a similar nature, is the blue mortar, commonly used in London, for setting the coping of buildings and other works much exposed to the weather. It is made with coal cinders and lime, but is seldom prepared with the requisite attention.

Ash-mortar is used in some parts of England, and is prepared by slacking two bushels of fresh meagre lime, and mixing it with three bushels of wood ashes; this mass is to lie till it is cold, and then to be well beaten; in this state it is kept for a considerable time without injury, and even with advantage, provided it be thoroughly beaten twice or thrice over before it is used. This cement is superior to terras mortar, in situations alternately exposed to wet and dry; but under water, terras mortar has the advantage.

The scales which are detached by the hammering of red-hot iron, have been long known as an excellent material in water-works. Mr. Smeaton appears to have been the first person who tried the relative strength of mortar made of the oxide of iron, and several other compositions. The scales being pulverized and sifted, and incorporated with lime, are found to produce a cement equally powerful with puzzolana mortar, when employed in the same quantity. Mr. Smeaton having been successful in his experiments on these materials, was induced to try others of a similar nature. Having substituted roasted iron ore for the scales, he found that this also gave to mortar the property of hardening under water, though it required to be used in greater proportions than either puzzolana or terras. Two bushels of argillaceous lime, two of iron ore, and one of sand, being carefully mixed, produce 3.22 cubic feet cement, fully equal to terras mortar. If the common white lime be employed, it would be advisable to use equal quantities of all the three ingredients.

With respect to the water used in the preparation of aquatic cement, that of rivers or ponds, where it can be procured, is to be preferred to spring water: but for works exposed to the action of the sea, it is usually more convenient, and equally advantageous in other respects, to use salt water.

The Loriot-mortar is a composition which at one time had obtained considerable celebrity in France, and was employed in many large works. It was invented, about seventy years ago, by M. Loriot, who imagined that he had discovered the process used by the Romans. The principle of the invention consisted in adding to any quantity of mortar, made in the usual way with lime and sand, but prepared rather thinner than usual, a certain portion of quick-lime in powder. The lime-powder being well incorporated with the mortar, the mass heated, and in a few minutes acquired a consistence equal to the best plaster-of-Paris; at the end of two days it became as dry as an ordinary cement at the end of several months; and when the ingredients were well proportioned, it set without any cracking. The quantity of powder varied from $\frac{1}{4}$ to $\frac{1}{6}$ of the other materials, according to the quality of the lime: too much, burning and drying up the mass; and with too little, its peculiar advantages being lost. The proportions are essential, but can only be determined by actual experiment.

Loriot's process was at one time, as we have observed, very much in vogue, but has now fallen into disuse. Founded on the false conception that the induration of mortars was the mere result of a more or less rapid desiccation, and presuming it to be possible to obtain this end by the introduction of a powerful absorbent, it met with the usual fate of error, and sunk into disrepute.

Mr. Smeaton says of this composition—"I have made trial of this method, both in small and in large; for however little likelihood of advantage a proposition may contain, yet, when this concerns a physical process, nothing can be safely concluded but from actual trial; and I must candidly own that the effect was much better than I had expected; for I found the composition not only set more readily than mortar as commonly made up, but much less liable to crack, and consequently, if this cement was made use of in water-building, it was less apt to re-dissolve, because it would more speedily get set to a firmer consistence, and so as more ably to resist the water from entering its pores; but when the water was brought upon it, in whatever state of hardness it was at the time, it at best remained in that state without any further induration, while the water remained upon it; and, as I expect, would so remain, till it had some opportunity of acquiring hardness by further drying."

Indeed, for the purpose of quick concretion, various materials are recommended to be added, such as brick and tile powder, and forge scales. The following is an approved receipt: one measure of bricks, finely pounded; two measures of fine river-sand; old slacked lime in sufficient quantity to make a mortar in the usual manner, and sufficiently liquid to quench the lime-powder, which is added to the same quantity as that of the pulverized bricks.

It is somewhat extraordinary, that a process similar to the composition of the Loriot-mortar is described in *A Treatise on Building in Water*, by George Semple, printed in Dublin, 1776. In discoursing on the good qualities of the roach-lime of Ireland, Mr. Semple remarks, that "it has some useful qualities, not much known among the generality of workmen. As, for instance, our lime-stone will make exceeding good terras for water-works, for which purpose you are to prepare it thus: get your roach-lime brought to you hot from the kiln, and immediately pound, or grind it with a wooden maul, on a smooth large stone, on a dry boarded floor, till you make it as fine as flour; then, without loss of time, sift it through a coarse hair or wire sieve, and to the quantity of a hod of your setting mortar (which on this account should be poorer than ordinary) put in two or three shovelfuls of this fine flour of the roach-lime, and let two men, for expedition's sake, beat them together, with such beaters as the plasterers make use of, and then use it immediately. This, I can assure you, will not only stand as well, but is really preferable to any terras." The memoir of M. Loriot was published in 1774, only two years previous to this treatise of Semple, who appears to have been a man rather of practice and experience than of reading; and, besides, in the book quoted from, he expressly, though incidentally, mentions his ignorance of the French language. We are justified, therefore, in stating that the knowledge of the advantages of mixing quick-lime powder in mortar, was not confined to M. Loriot, though it might have been an original invention in him, and that he was the first who drew the public attention to the process, and used it in any considerable works.

We have now to notice the valuable Treatise of M. Vicat, the celebrated French engineer, on the Composition of Mortars and Cements. This scientific and elaborate work has been made extensively known in this country, by the able manner in which it has been translated by Captain J. T. Smith, of the Madras Engineers. The labours of this gentleman have given increased value to M. Vicat's work, and the numerous notes, tables, and other information, added to the original work by Captain Smith, will be found most useful to the professional man, and well worth his careful and attentive study.

In this place we shall briefly describe the mode pursued by M. Vicat in the manufacture of the *Artificial Hydraulic Limes*, he so strongly recommends. We shall have occasion to return to his work hereafter, when on the subject of CONCRETE.

The practice of M. Vicat seems to have been principally directed to the adoption of the hydraulic limes, in preference to the more energetic cements so generally used in this country, but his investigations have been conducted on so comprehensive a scale, that the processes laid down by him for the manufacture of artificial hydraulic compounds are capable of application to almost every requirement of the Architect or Engineer, or to almost every situation.

The opinion so decidedly expressed by M. Vicat, that the superior adhesion of the hydraulic limes, must inevitably lead to their general adoption in this country, in preference to our (so-called) Roman cements, has been much combated by practical men. It may be said, without entering into a discussion of the question, that it appears to be one on which a contrariety of opinion may be occasioned by a difference of situation and circumstances. Thus, in comparing the merits of the two systems, it is important to consider, that, in one, the means of minute mechanical division are an essential element, in the other that it is unnecessary; and that this element, which in one situation may be obtained at a cheap rate, in another may be expensive and unattainable.

The hydraulic limes, therefore, which do not require to be *ground* previous to use, are at all events most suitable for those situations where the facilities of mechanical agency cannot be resorted to, while the *ground cements* are better adapted to the vicinity of a large capital, where it is of little importance that the builder becomes dependent upon others for his supply.

The difference, in fact, consists in this, that the ground cements, of whatever kind, will ever be furnished by *manufacturers*, whereas the hydraulic limes may at all times be

prepared by the common workman, without machinery, and at a cost not much exceeding that of common lime.

The description given by M. Vicat of the mode in which the artificial hydraulic limes are prepared is as follows:—"The artificial hydraulic limes are prepared by two methods: the most perfect, but alsothe most expensive, consists in mixing with rich lime slacked in any way, a certain proportion of clay, and calcining the mixture; this is termed artificial lime *twice kilned*."

"By the second process, we substitute for the lime any very soft calcareous substance (such, for instance, as chalk), which it is easy to bruise and reduce to a paste with water. In this way a great saving is effected, but at the same time is procured an artificial lime of good quality, though not equal to that derived from the first process, in consequence of the rather less perfect amalgamation of the mixture."

"We see that by being able to regulate the proportions, we can also give to the factitious lime whatever degree of energy we please, and cause it at pleasure to equal or surpass the natural hydraulic limes."

"We usually take twenty parts of dry clay to eighty parts of very rich lime, or to one hundred and forty of carbonate of lime. This refers to the lime in the unslacked condition, or to the uncalcined mineral. If the lime be slacked, the proportion should be increased to 110 parts. But if the lime or its carbonate should already be at all mixed with clay in the natural state, then fifteen parts of clay will be sufficient. Moreover, it is proper to determine the proportions for every locality."

"The mixture here described," adds Captain Smith in a note, "is such as to produce the hydraulic limes, whose properties are similar to the Aberthaw, the analysis of which shows it to correspond nearly with the proportions here recommended, as it consists of 86.2 of carbonate of lime to 11.2 clay, (with 2.6 water and carbonaceous matter), being at the rate of 18.2 parts clay, to 140 of the carbonate of lime. The cements now in use in England, are much quicker setting than these, and differ in being unslacked. They contain a greater proportion of clay, but may be manufactured artificially with equal ease, by combining such relative quantities of chalk, or lime, and clay, as will suit the purpose intended. Parker's Patent Cement, as analyzed by Sir Humphrey Davy, contains 45 per cent of clay to 55 carbonate of lime; the Yorkshire cement, 34 clay to 62 carbonate of lime; the Sheppey, 32 clay to 66 carbonate of lime; and the Harwich, which is a quicker-setting cement, 47 clay to 49 carbonate of lime." It seems to be evident from the experiments of M. Vicat, that the manufacture of artificial cements may be almost infinitely varied by the admixture of different ingredients. The character, quality, and proportions of these must be the result of actual practice and experiment, for so different may be the chemical properties of apparently similar materials, that no results, however successful in one locality, can be trusted to with certainty in another. It is only necessary to add, that in all cases, particular attention should be paid to the perfect amalgamation of the materials; and the degree of calcination best suited to it should be carefully observed, before attempting the manufacture on a large scale.

The process made use of at a manufactory of artificial lime at Meudon, near Paris, is thus described by M. Vicat—"The materials made use of are chalk of the country, and the clay of Vaurigard, which is previously broken up into lumps of the size of one's fist. A millstone set up edgeways, and a strong wheel with spokes and felloes, firmly attached to a set of harrows and rakes, are set in motion by a two-horse gin, in a circular basin of about two metres (six feet and a half English) radius. In the middle of the basin is a pillar of masonry, on which turns the vertical arbor to which the whole system is fixed: into this basin, to which water is conveyed by means of a cock, they throw successively four measures of chalk, and one measure of clay. After an hour and a half working, they obtain about 1.50 metres cube (nearly 53 cubic feet English), of a thin pulp, which they draw off by means of a conduit pierced horizontally on a level with the bottom of the basin. The fluid descends by its own weight; first into one excavation, then into a second, then a third, and so on to a fourth or fifth. These excavations communicate with one another at top; when the first is full, the fresh liquid, as it arrives, as well as the supernatant fluid, flow over into the second excavation; from the second into the third, and so on to the last, the clear water from which drains off into a cesspool. Other excavations, cut in steps like the preceding, serve to receive the fresh products of the work, whilst the material in the first series acquires the consistency necessary for moulding. The smaller the depth of the pans in relation to their superficies, the sooner is the above-mentioned consistency obtained.

"The mass is now subdivided into solids of a regular form, by means of a mould. This operation is executed with rapidity. A moulder, working by the piece, makes on an average five thousand prisms a day, which will measure about six cubic metres (211.8 cubic feet English). These prisms are arranged on drying shelves, where in a short time they acquire the degree of desiccation and hardness proper for calcination."

These artificial limes are intended to supply the place of the natural ones in those countries where argillaceous limestone cannot be obtained. The price at which they were sold in Paris a few years back, was about £2 5s. per cubic yard English.

Maltha, and *mastic*, are cements, whose hardness depends on the oily or mucilaginous substances that enter into their composition. The use of these is at present very limited in Europe; but they were highly esteemed by the ancients, especially for stucco. The *maltha* of the Greeks seems to have been more simple than that employed by the Roman architects; at least we are informed, that Panæmas, the brother of Phidias, lined the inside of the temple of Minerva, at Elis, with stucco, in which the usual ingredients of sand and lime were mixed up with milk, instead of water, some saffron being added to give it a yellow tinge. The Roman *maltha*, according to Pliny, was prepared as follows: Take fresh-burnt lime, and slack it with wine, then beat it up very well in a mortar, with hogs' lard and figs: this cement, if well made, is excessively tenacious, and in a short time becomes harder than stone; the surface to which it is to be applied is to be previously oiled, in order to make it adhere. Another kind almost equally-strong, and considerably cheaper, was prepared by beating up together fine slacked lime, pulverized iron scales, and bullocks' blood.

In the preparation of *maltha*, as well as of every other kind of mortar, so much depends on the manipulation, and on the care and long beating of the ingredients, that those countries in which labour is of the least value, possess, in general, the best mortar. Hence, no doubt, principally arises the unrivaled excellence of the mortar made by the Tunisians, and other inhabitants of the northern coast of Africa. Dr. Shaw gives the following account of their manner of preparing their mortar: One measure of sand, two of wood-ashes, and three of lime, being previously sifted, are mixed together, and sprinkled with a little water; after the mass has been beaten some time, a little oil is added: the beating is carried on for three or four days successively, and, as the evaporation in

that hot climate is considerable, the cement is kept in a proper degree of softness by the alternate addition of small quantities of water and oil. The cement, being completed, is applied in the usual manner, and speedily acquires a stony hardness.

The term *maltha* is also applied to a variety of bitumen or mineral pitch of a viscid and tenacious character; unctuous to the touch, and exhaling a bituminous odour. This substance, as also Asphalte, (see ASPHALTE,) has been successfully used as a cement.

The celebrated *chunam*, of India, is a species of *maltha* which has been used in that country from time immemorial. The method in which it is prepared at Madras is as follows:—

Take fifteen bushels of pit-sand, and fifteen bushels of stone-lime; slack the latter with water, and when it has fallen to powder, mix the two ingredients together, and let them remain for three days untouched. Dissolve 20 lbs. of molasses in water, and boil a peck of *gramm*, (a kind of pea,) and a peck of mirabolans to a jelly; mix the three liquors, and incorporate part of the mixture very accurately with the lime and sand, so as to make a very fluid cement; some short tow is then to be beaten well into it, and it will be fit for use. The bricks are to be bedded in as thin a layer as possible of this mortar; and when the workmen leave off, though but for an hour, the part where they recommence working is to be well moistened with some of the above liquor before the application of fresh mortar. When this composition is used for stucco, the whites of four eggs, and four ounces of buttermilk, are to be mixed up with every half bushel of cement, and the composition is to be immediately applied.

Mastic is an external composition possessing peculiar properties, which, in some cases, render it superior to Roman cement, having the power of resisting heat and adhering to iron, copper, and even glass, with equal tenacity. It is generally applied to the exteriors of mansions, but it may also be very beneficially used for laying the floors of halls, kitchens, &c.

Mastic was first introduced from France by Hamlin, but is now sold only by Messrs. Francis and White, at Nine Elms. It is composed of pounded stone, silver sand, litharge, and red lead, and, when manufactured, has the appearance of very fine sand. The manner of working Mastic is entirely different from that of Roman cement.

To one cwt. of Mastic add one gallon of linseed-oil, and let them be well incorporated by the labourer, which must be effected by treading them together with the feet until the amalgamation is complete, which may be easily ascertained by smoothing a portion of the mixture with the shovel: should any bright spots be observable, the treading must be again and again repeated until they completely disappear, when it is considered fit for use.

The manner in which Mastic is used is as follows:—The joints of the brickwork being well cleaned out, the work must be correctly plumbed up by means of flat-headed nails, and screeds, for the guidance of the floating-rule, formed with Roman cement, and kept about one inch in breadth. This being done, the bricks must be well saturated with boiled linseed-oil of the best quality, and the Mastic laid on with the hands, assisted occasionally by the laying-trowel, until the space between the screeds be covered to the thickness required. The floating-rule is then passed carefully over the work; and when the space between the screeds is sufficiently filled up, it must be floated with a hand-float, composed of sycamore or beech, until it assumes the same appearance as highly-polished stone. Thus a space of large dimensions must be followed up until the whole is completed, when the screeds must be cut out, their places filled with Mastic, and compactly hand-floated into the rest of the work.

Within the last few years various compositions have been invented for the covering of the exterior of buildings, such as Roman Cement, Terra Cotta, Bailey's Composition, and a host of others, all more or less patronized by the public.

It would be impossible for us to give descriptions of all these compositions; but we shall shortly explain the mode of preparing and using the *Roman cement*. This cement, familiarly known among plasterers as *Compo*, was first introduced to public notice by Messrs. Parker and Wyatt, who took out a patent for it, and who succeeded in obtaining for it an extensive sale.

It is prepared from the kind of stone called clay-balls, or septaria, by being, after a manner of manufacturing plaster first broken into pieces of a convenient size, slowly calcined in kilns or ovens, and afterwards ground to a fine powder, and put into proper casks, great care being taken to preserve it from damp. Two parts of this composition, with three parts of clean grit-sand, will form a very durable substitute for stone. In selecting the sand, great care must be taken to procure it free from clay or mud, and of a sharp and binding quality, or it must be washed until perfectly clean.

This composition, when it is intended to *compo*, as it is termed, the exterior of a building, is thus used:—

After the walls have been well soaked with water, the cement must be prepared by the hawke-boy on a stiff board made for the purpose, adding as much water as brings it to the consistency of paste, but no more must be mixed than can be used in ten minutes. It must be laid on with the greatest possible expedition, in one coat of three-quarters of an inch in thickness, and after being well-adjusted with the floating-rule, the hand-float must be incessantly used to bring it to a firm and solid surface before it sets, which it does in about fifteen minutes.

The work should then be drawn and jointed to imitate well-bonded masonry, and afterwards coloured with a wash composed of five ounces of copperas to every gallon of water—a sufficient quantity of fresh lime and cement—and to the whole adding the colours necessary to imitate any particular stone that may be required.

Terra Cotta, or artificial stone, is an excellent and durable composition, advantageously used at the present day for all kinds of exterior decoration. It is a compound of pipe-clay, stone-bottles, glass, and flint, well pounded together, and sifted through a fine sieve, a small portion of silver-sand afterwards added.

Bailey's Composition is also a valuable invention, which has been used with great advantage in various situations, without being at all injured by winter. The exteriors of many of the public buildings in the metropolis are covered with this composition, amongst which is the Colosseum in the Regent's Park.

It is simply a mixture of lime and sand, the strength of the lime being preserved by the peculiar manner in which it is prepared. In its manufacture, chalk should never be used; it ought always to be made from lime-stone, or carbonate of lime. The lime, being taken before being slacked and ground to powder, must be placed in iron-bound casks to prevent the admission of air or damp. When used, it must be mixed with one-third its quantity of sharp river-sand, the manner of working it being the same as that of Roman cement. *See* MORTAR, GROUT, STUCCO, and CONCRETE.

CEMETERY, a sacred place, set apart for the burial of the dead. The term is of Greek derivation, signifying "a place of rest or sleep," and was applied by the early Christians to common places of interment.

The subject of burial in towns has of late occupied so prominent a place in public estimation, that the description

of a few of the great receptacles for the dead lately established in or near the metropolis, cannot be out of place in a work of this kind; the more especially, that the professional talent of the architect has, not unfrequently, been called into action, to furnish designs for the buildings connected with public cemeteries, if not for the ornamental gardens, since it has become the fashion of the day to make these "cities of the dead."

From the very earliest ages the disposal of the bodies of the dead has been a necessary, and with many nations, a sacred duty. Among some we find that a superstitious veneration for those who had "passed away;" the necessity of funeral rites to secure the future happiness of the deceased; and the crime attached to the violation of the tomb, formed a part both of their civil and religious code. The practice of burying the dead in the earth is probably the oldest, as it is the simplest mode of disposing of them: but the custom of burning the body, and afterwards collecting the ashes, and depositing them in a tomb, or urn, became very general amongst the Greeks and Romans. The Egyptians do not seem to have ever adopted this practice; and even amongst the ancient Greeks and Romans, it seems likely that interment in the earth was mostly resorted to by the lower orders. At the present day, all European nations deposit their dead in the earth, and the ceremony of burning is extinct.

The establishment of public cemeteries is now becoming general in the neighbourhood of large cities; a practice probably suggested to us by the customs of the Orientals, with whom the burial-places of their departed friends are objects of peculiar care, and who cultivate, with extreme affection and solicitude, the flowers and trees with which it is their delight to adorn them.

"Among the first objects that present themselves to a stranger entering Turkey," remarks a recent writer, "are the groves of cypress extending in dark masses along the shores. These are the last resting-places of the Turks; and their sad and solemn shade, far more gloomy than any which Christian usage has adopted, informs the traveller that he is now among a grave and serious people.

The situation of cemeteries is of great importance, both with regard to the public health, and from considerations of convenience. Among the Greeks we find that they were usually without the cities. Among the Romans the tombs were generally placed by the sides of the public roads. The early Christians followed the custom of the Romans, but they afterwards transferred their burial-places to the vicinity of the churches, and within towns. This insalubrious practice, it is to be hoped, will soon entirely cease, and the health of the living be no longer endangered by the too close proximity of the graves of the dead.

Cemeteries should be placed on high ground, and to the north of habitations, so that southerly winds should not blow over the houses, charged with the putrid exhalations; low wet places should be avoided, and care should be taken that bodies be not interred near wells, or rivers, from which people are supplied with water.

It may not be uninteresting here to state that extra-mural or suburban cemeteries, formed part of the plan of the celebrated Sir Christopher Wren, for the rebuilding of London after the grea tfire. "I would wish," says he, "that all burials in churches might be disallowed, which is not only unwholesome, but the pavements can never be kept even, nor the pews upright; and if the church-yard be close about the church, this is also inconvenient, because the ground being continually raised by the graves, occasions in time a descent by steps into the church, which renders it damp, and the walls green, as appears evidently in all old churches." He then proceeds to recommend, that a piece of ground, being purchased in the fields, should then be "enclosed with a strong brick wall, and having a walk round, and two cross walks, decently planted with yew-trees. The four quarters to serve four parishes, where the dead need not be disturbed at the pleasure of the sexton.

"In these places beautiful monuments may be erected; but yet the dimensions should be regulated by an architect, and not left to the fancy of every mason; for thus the rich with large marble tombs would shoulder out the poor: when a pyramid, a good bust, or statue on a proper pedestal, will take up little room in the quarters, and be properer than figures, lying on marble beds; the walls will contain escutcheons and memorials for the dead, and the real good air and walks for the living."

Though the cemeteries which have been formed are pronounced to be only improvements on the places of burial in this country, and far below what it would yet be practicable to accomplish; they have indisputably been viewed with public satisfaction, and have created desires of further advances by the erection of national cemeteries. Abroad the national cemeteries have obtained the deepest hold on the affections of the population. They have been established near to all the large towns in the United States. To some of them a horticultural garden is attached; the garden-walks being connected with the places of interment, which, though decorated, are kept apart. These cemeteries are places of public resort, and are there observed, as in other countries, to have a powerful effect in soothing the grief of those who have departed friends, and in refining the feelings of all.

At Constantinople, the place of promenade for Europeans is the cemetery at Pera, which is planted with cypress, and has a delightful position on the side of a hill overlooking the Golden Horn. The greatest public cemetery attached to that capital is at Scutari, which forms a beautiful grove. In Russia, almost every town of importance has its burial-place, at a distance from the town, laid out by the architect of the government. It is always well planted with trees, and is frequently ornamented with sculpture. Nearly every German town has its cemetery, planted and ornamented. In Turkey, Russia, ard Germany, the poorer classes have the advantages of interment in the national cemeteries.

One of the most celebrated cemeteries in Europe is that of Père la Chaise, but in this, as in all the cemeteries of Paris, it has been a subject of complaint, that the graves of the poor are neglected and little cared for, amidst the splendid monuments and sculptured ornaments which mark the tombs of the higher classes.

The first attempt at a metropolitan cemetery, in imitation of that of Père la Chaise, was made by the General Cemetery Company, who, in the year 1833, opened to the public their new and extensive burial-ground at Kensall Green. This cemetery occupies above fifty acres of ground; which is tastefully laid out with flowers and plants; well-gravelled walks lead to various parts of the ground; and yews, evergreens, and shrubs, deemed appropriate to a place of sepulture, ornament and diversify the landscape. On the road-side, the cemetery is bounded by a high wall, affording protection and seclusion; on the other side, towards the canal, an open iron palisading permits an uninterrupted view of the country, which here presents a prospect both extensive and beautiful. At the entrance there is a handsome gateway, from which a central walk leads to the church in the *consecrated* portion of the cemetery. In this building are solemnized the funeral rites according to the Church of England. In front of the church a large circle is appropriated to many of the more splendid

tombs and mausoleums, and beneath it are extensive catacombs.

In the *unconsecrated* part of the cemetery, set apart for the burial of Dissenters of every denomination, a neat chapel has been erected for the performance of service according to their several forms of worship. The principal feature of this chapel is a rather handsome Doric colonnade, and near it also are catacombs.

The etablishment of the cemetery at Kensall Green was immediately followed by that of several others in the suburbs of London; one of the most picturesque of these is Highgate Cemetery, situated on the rising slope of the hill behind Highgate Church. Here, the natural beauty of the ground has been tastefully made use of, and the result produced is pleasing, if viewed as a pleasure-garden, though certainly conveying but little of that solemnity of thought and feeling we are accustomed to associate with a burial-place for the dead.

The southern entrance, in Swain's Lane, is in a style compounded of Gothic of all periods, exhibiting more of tawdry decoration than the sobriety which should have characterized it. The Egyptian style has been selected for the catacombs, which are approached through an arched avenue, with an entrance flanked by two obelisks. This passage, in the upper part of the grounds, is lined on each side by a range of sepulchral chambers, and leads into another avenue, forming a circular walk between similar chambers, each of which has its Egyptian doorway. These sepulchres, amounting altogether to forty-six, besides eighteen others in the first mentioned avenue, form as many sides of two polygons, an outer and inner one. Midway is an ascent, first by a single flight of steps, and then by others on each side, leading to a terrace overlooking the catacombs, from which they present a striking appearance; the summit of the inner polygon being covered with earth, and having a large cedar in the centre. The back wall of this terrace is in a semi-Gothic style, crowned by a fancy open-work parapet, placed before another terrace, under the south end of the Gothic Church, erected a few years ago by Mr. Vulliamy. The prospect from this terrace is exceedingly beautiful.

Norwood Cemetery occupies about forty acres, on the north-west side of a hill to the east of St. Luke's, Norwood. The entrance is an open arch, which, with the lodge adjoining it, are in much better taste than that of Highgate, although, had there been a gateway, the design would have been greatly improved. There are two chapels—one for members of the Church of England, the other for Dissenters — though varying somewhat in design, there is great similarity in their style, which is a sober, but correct Gothic. The principal objection is the injudicious position of these two buildings, which, from being too near together, neither form distinct architectural pictures, nor group so as to form one design. The architect is Mr. W. Tite.

Abney Park Cemetery contains about thirty acres, and displays evidence of a simple and pure taste, in its buildings and general arrangement. The entrance, if wanting in architectural composition, has something bold and effective in its general appearance. The four piers are lofty and well-proportioned masses, constructed of Portland stone, upon granite plinths, and are surmounted by handsome coved cappings, in the Egyptian style. The lodges are in the same style, and extend the frontage to 118 feet, 40 of which are occupied by the piers and gates in the centre. The effect of this entrance is greatly enhanced by the park-like aspect of the grounds, and the fine old trees with which they are adorned. Nearly in a line with the entrance is the chapel, in the early pointed style, with lancet windows. The architect is Mr. W. Hosking.

The South London Cemetery comprises fifty acres of dry well-drained land, in one of the most beautiful spots within the vicinity of the metropolis. It is situate at Nunhead, between Peckham Rye and New Cross. The grounds are most tastefully laid out—there are handsome lodges, a residence for the superintendent, episcopal and dissenters' chapels, and extensive catacombs. The architectural arrangements were superintended by Mr. Bunnings.

The West of London Cemetery, situate at Earl's Court, consists of about forty acres. The buildings, &c. in the Italian-Doric style, are of a similar character to those previously described, and the grounds are laid out in the pleasure-garden manner, so popular with those who have the management and designing of Cemeteries. It would be well, were a few hints taken from the solemn, beautiful burial-places of the Orientals, in laying out such establishments in this country.

CENOTAPH (from the Greek, *κενοταφιον*) an honorary monument erected to the memory of the dead, when the funeral rites have been performed in some other place.

CENTAUR, in heathen mythology, a fabulous monster, with the head and breast of a man, and the body of a horse.

CENTERING, the act of making a centre, or the centre itself. *See* CENTRE.

CENTERING TO TRIMMERS, the centre made to support a brick arch suspended between the wooden trimmer and the wall, for supporting the hearth or slab.

CENTRE, or CENTER, (Greek, *κεντρον*, *a point*, or *puncture*,) in a general sense, denotes a point equally remote from the extremes of a line, figure, or body; or the middle of a line, or plane, by which a figure or body is divided into two equal parts; or the middle point, so dividing a line, plane, or solid, that some certain effects are equal on all its sides.

CENTRE OF GRAVITY, that point at which all the weight of a mass might be collected, without disturbing the equilibrium of any system of which the mass forms a part. Thus, if a lever were balanced by means of two solid spheres of uniform density hung at the ends, the equilibrium would still remain, if all the matter of either of the spheres could be concentrated at its centre. The centre of the sphere is then its centre of gravity.

CENTRE OF PRESSURE, the point at which the whole amount of pressure may be applied, with the same effect as it has when distributed.

CENTRE, in building, is a combination of timber-beams, so disposed as to form a frame, the convex side of which, when boarded over, corresponds to the concavity of an arch; or the wooden mould, used for turning an arch of stone or brick during the time of erection.

Centre of a cylindric or cylindroidal arch, which rises more than the breadth of a plank, is a number of boards supported transversely by one or more vertical frames, or trusses, as the length of the cylinder, or that of its axis, may require.

Centre for a groined arch upon a rectangular plan is thus constructed: Make the centre for one of the cylinders, or cylindroids, viz. that of the greatest diameter, when there is a difference, as if there had been no other cylinder crossing it; find out the places on the surface of this cylindric or cylindroidal centre, where the surface of the transverse vault would intersect: fix the whole ribs on the cross vault, and parts of ribs on the surface of the vault already completed, observing to keep the outer edge of these ribs the thickness of the boards wi hin the intended surface of the intrados of the arch; when this transverse vault is boarded over, the boards will intersect the lines drawn on the first centre, and the surfaces of the boards of each vault will form the

true surface of the groined centre, on which the stone or brick arch is to be turned.

The frames or trusses which support the boarding are frequently called *ribs;* and the short ribs which are fixed to the boarding, and made to range with the whole ribs, are called *jack-ribs.*

Under the word Stone-Bridge, &c., the theory and construction of arches will be described; in the present article we propose to show how the arch-stones are supported till the arch is completed; and the most commodious and least expensive manner in which this can be accomplished.

The proper construction of such supports, or the best mode of framing the centres for large works, has always been considered so important a subject, that it has occupied the attention, and exercised the talents, of the most eminent engineers and architects. The principal object to be kept in view is, to fix the various parts of the centering in such a manner, as to support, without change of shape, the weight of the materials that are to come upon them, throughout the whole progress of the work, from the springing of the arch to the fixing of the key-stone. This object has not always been sufficiently attended to by the professional men, either of this, or of other countries; for in many instances it has been ascertained that the centres of bridges, from the injudicious principles of their construction, have changed their shape considerably, or entirely failed, before the arch was complete; and in consequence of change of shape only, the arches built upon them have varied, both in form and strength, from the intention of the engineer. In the large works of this kind, however, erected in Great Britain, our best engineers have constructed their centres on principles calculated to support every weight, and resist every strain to which they might be exposed.

"The qualities of a good centre," says Tredgold, "consist in its being a sufficient support for the weight or pressure of the arch-stones, without any sensible change of form throughout the progress of the work, from the springing of the arch to the fixing of the key-stone. It should be capable of being easily and safely removed, and designed so that it may be erected at a comparatively small expense."

The centre of a large vault, as that of a bridge, is constructed of trusses disposed equidistantly in vertical parallel planes, and boarded over so that the convexity of the boarding may coincide with the intended internal intrados of the arch. The distance of the ribs may be disposed at from three to eight feet, according to the strength of the boarding and weight of the arch. In very large works, a bridging is laid for every course of arch-stones, with blockings between, to keep them at regular distances. The ring-stones do not always rest upon these bridgings; planks being sometimes put between, that they may be cut away afterwards, to separate the centre and the intrados from each other, in order to ascertain whether there are any settlements, to repair the damages, and put the arch in a state of equilibrium.

Where the river is not navigable, the trusses may be constructed with a beam at the bottom: in this case, there is no difficulty. The forms for the trusses of roofs with tie-beams, may form the grand or principal part of the truss for the centre. But when the river is navigable, the centre requires as large an opening as is consistent with its strength, in order that vessels may pass under it; and as the horizontal tie is interrupted, this disposition of the timbers will require much greater skill in the carpenter.

If the river over which a bridge is to be built be not navigable, the manner of constructing the centre is so easy, that it would be unnecessary to give any examples here; but where the river is navigable, instead of the horizontal tie, a number of ties are disposed around the polygon, forming the interior part of the centre; but as in many practical cases the most judicious and well-skilled theorist might be deceived as to the equilibrium of the arch to be supported, or the points in which it has the most tendency to fall, it would be very difficult to say what are ties and what are strutts; and even if the true pressure of the arch could be ascertained, the knowledge of this alone would not be sufficient; for the same parts of the vaults, in the process of execution, vary their pressure in every succeeding additional part, and what was a tie at one time, becomes sometimes a strutt; while a strutt, on the contrary, will become a tie, either in building, or at the completion of the vault. This ought to be well considered; and where the pressure is doubtful, or any of the lengths of timber forming the centre are ascertained to be in the two different states above mentioned, such timbers should be made to act in either case.

Though the timbers upon which the vault immediately rests, cannot be supported transversely throughout, the other pieces, which support the arch from the several pressing points, may all be made to act, by a judicious arrangement, in the direction of their lengths. The abutting joints, which are pressed, will be sufficiently resisted, when their shoulders are made perpendicular to the direction of their force, and with the small tenon; but if the timbers are drawn in a direction of their length, the joints ought to be strapped.

The beauty of every truss is to have as few quadrilaterals as possible. All the openings should be triangles: the intersection of the timber should be as direct as possible. Oblique directions exert prodigious strains, which require timbers of very large sections to withstand them, and press upon the abutments so much as to make the whole truss sag by the compression of the intermediate joggles.

If proper attention be paid to these circumstances, and the bearings of the timbers be well ascertained, a centre, constructed upon such principles, must answer its intended purpose, provided a proper estimate be taken of the communicating forces during the execution of the vault, and the centre be well secured at its abutment.

A centre for the arch of a bridge over a navigable river, may either be accomplished with one centre around the interior of the entire arch, supported between the piers; or, if the span of the arch will admit, the aperture may be subdivided into two or more apertures, by one or more supporters, each consisting of one or more posts of wood, braced together when necessary; these supporters, together with the sides of the stone piers, support the centre of the aperture, on which the stone arch is to be erected over the whole. By this mode, the centering is much more simple in its construction and requires fewer timbers, and these of smaller scantlings than when made in one centre.

If a centre be truly constructed, every point of the vault to be built ought to be supported, without giving any transverse strain to the incumbent part of the centre: but this is impracticable; for, as it would require a multiplicity of joints, it would, from the shrinking of the timber, be less sufficient than if composed of few pieces, supporting only a certain number of points disposed at judicious distances, leaving the intervals to be supported by timbers in which the superincumbent part of the arch might act transversely, but still presenting such a resistance, as not to be materially bent or put out of form by the load of the arch above.

By these precautions, the centre will be constructed so as not to yield, or give way, though the load should vary during the erection of the arch, and will stand as firm as if the whole had been constructed out of a single solid: the only thing to be attended to, as before observed, being to make

the timbers sufficiently strong to withstand either tension or compression.

There are several other principles of constructing the ribs of centering; one of these may be that of a large truss, spanning the whole opening, having its vertex supporting the summit of the arch, and its rafters, or principal braces, supporting other subordinate trusses which resist the pressure of the arch at other intermediate points.

Of this kind is that of the bridge of Orleans, by M. Hupeau, one of the boldest centres ever executed in Europe. Another principle is that of two independent trusses, one supporting the sides or haunches of the arch, and the other the crown. Of this construction was the centering of the nave and transepts of St. Peter's church, at Rome, by Michael Angelo, and two centres by Pitot. Another principle of centering is that of inscribed equilateral polygons; that is, the exterior beams, supporting the curve, are of equal lengths, and joined together in the form of a polygon: another polygon is formed within this, having its angles in the middle of the sides of the former, and so on, alternately, until there are as many polygons inscribed as will make the centering sufficiently strong or stiff. This mode of centering may be of two kinds: one, when the angles are fixed at their junction to the sides of the last polygon with bolts; bridles, or double truss-pieces, being put over the angles to prevent a transverse strain at the section of the timbers where the two pieces meet, and to support the curve above. The other kind is, when the polygons act independently of each other; these polygons are brought into action by bridles, which support the curve, and act upon the angular points of each other's polygon. Of this kind were the centering of the bridges of Cravant, Nogent, Mayence, and Neuilly, constructed by Perronet. Though these centerings have been executed to very large spans, the last mentioned being 120 feet, their equilibrium is by no means so secure as when the angles of the inner polygon are fastened to that immediately preceding, as is evident from the information given of the erection of these bridges, by the ingenious architect who has favoured the world with a treatise on this subject.

Another principle of centering is that of Westminster and Blackfriars bridges, London. They consist of a series of trusses, each supporting a point in the arch, the principal braces having their lower extremities abutting below, at each end of the centering, on the striking-plates, and at the upper end, upon apron-pieces, which are bolted to the curve that supports bridgings for binding the pieces which compose them together at their junction. There is one disadvantage under which this mode labours; that is, the frequent intersection of the principal braces with each other: they must either be halved one upon the other, otherwise they must be discontinued, and made in various lengths. Both these modes diminish their lateral strength, and consequently make them much more liable to buckle than when whole; but of the two, that of halving is to be preferred; as by the braces being in one length, there can be no sagging occasioned by intermediate joggles, and the braces may be rendered sufficiently secure, laterally, by running straps longitudinally across the notched part on each side, bolting these straps to the braces.

Lastly, another mode of centering may be that of a number of quadrilateral frames abutting on each other, having their joints radiating to a centre, in the manner of the wedge-stones of an arch in masonry. These frames should all be resolved into triangles by one or two diagonals, according to the kind of strain, keeping in view that a piece, which is a tie in one diagonal, is, in the other diagonal of the same quadrilateral, a strutt; but if the kind of strain on any frame be not well ascertained, it would be better to place two diagonals, halved upon each other. The frames are to be secured with keys or bolts, and by this precaution each frame will be rendered quite immovable.

The general principle of construction is a series of triangles, of which every two are connected by a common side.

Plate I., *Figure* 1. Let A B C D E F G be the curve of an arch which requires a centre; let the points A, B, C, &c., be connected so as to form the equilateral polygon, A B C D E F G, and join A C, C E, and E G; the timbers thus disposed will form three triangles, which may be looked upon as so many solids, revolvable about the angular points A, C, E, G; suppose now, that these are to be in equilibrium, the smallest force on either side would throw it down, and therefore, without other connecting timbers, it would be unfit for the purpose of a centre.

Figure 2. Let A B C D E F G be the curve of an arch which requires a centre; first, form the equilateral polygon, A B C D E F G, with the timbers A B, B C, C D, &c., and fix the timbers A C, C E, E G, as before, which will form three triangles movable round A, C, E, G; let the timbers B D and D F be fastened, and thus the whole will be immutable; so that if supported at the points A and G, and a force applied at any other of the angles B, C, D, or F, the timbers will be all in a state of tension, or in a state of compression, and the whole may be looked upon as a solid body; for suppose the triangle A B C to be supported at the points A and B, the point C, and the other two sides, B C, C A, will be fixed; and because B C D is a triangle, and the points B and C are fixed, the point D, and consequently the sides C D and D B; in like manner, since C D E is a triangle, and the points C and D fixed, the point E will also be fixed, and therefore the sides D E and E C. The same may be shown, in like manner, for the points F and G. Suppose, then, two equal and opposite forces applied at the points A and G, in the plane of the figure, the figure can neither be extended out, nor compressed together. The pieces A H, H B, and G I, I F, are of no other use than to make the centre stand firmly on its base. This disposition of the timbers will cause them to occupy the least possible space.

If the timbers are fixed at the points, *k*, *l*, *m*, *n*, *o*, *p*, *Figure* 2, the same immutability of figure may be demonstrated; for, suppose the points A and H to be fixed, the point *k* will also be fixed; the points A and *k* being fixed, the point B of the triangle A *k* B; again, the points B and *k* being fixed, the point *l* will also be fixed: in the same manner, all the remaining points, C, *m*, D, *n*, E, *o*, F, *p*, G, I, will be proved to be stationary in respect of the points A, H; and the whole figure being kept in equilibrio by any three forces, acting in the plane of the figure, at any three angles, the action of the forces will only tend to compress or extend the timbers in a direction of their length.

In the construction of this truss, the triangular parts may be constructed all in the same plane, as in Figure 1; and the pieces B D and D F may be halved upon the pieces C A and E G; but the utmost care must be taken to secure the several pieces concurring at each of the angles, by bolting or iron straps, as no dependence can be put in any such joint without iron: but perhaps the best method of any is to halve the thickness of the pieces A C, C E, E G, at the points C and E, and also the pieces A B, B C; C D, D E; E F, F G; at the points B, D, F: then bolting the ends A and C of the pieces B A, B C, the ends C and E of the pieces D C and D E, and the ends E and G of the pieces F E and F G, and then fixing double braces B D, D F, that is, fixing B D upon one side of the truss, and another upon the other side of the truss, opposite to it, also fixing D F upon one side, and another opposite to it.

The disposition of the timbers forming only a series of

quadrilaterals, gives nothing but immutability of figure. It can only derive its stiffness from the resistance of the joints.

Figure 3 shows the manner of forming a centre by two polygons, of which the interior one is secured to the exterior: in this there is no occasion for double trussing-pieces, as the parts of the inscribed polygon act either as strutts or ties to that of the circumscribing one.

Figure 4 is the manner of forming the rib for a centre, by two independent trusses; in this form of centering there is no occasion for bridles, or double trussing-pieces, as in those of Pitot, of the same construction.

Figure 5 is the manner of constructing a centre, according to Perronet, with four polygons, independent of each other, but with this improvement, that the lower extremities of each ring of polygons are framed into the two abutments; this gives a much firmer base than if they were all to meet at the same place, and renders the centre much stronger, by making the angles more acute. In this it becomes also necessary to have bridles, otherwise the exterior polygon only would be effective.

Figure 6 is the manner of constructing a centre with three polygons, which are all secured to each other. In this, truss-pieces become necessary, otherwise the angles of the inner polygon would bend the sides of that next to it.

Plate II., *Figure* 1, is the design of a centre, its principle being that of two roofs intersecting each other. In this example, the forces which are communicated to the various parts of the frame are resisted longitudinally, either by compression or extension; and no force is exerted transversely on any part, excepting the curved pieces in contact with the boarding supporting the arch-stones.

Figure 2 is the design of a centre; it is first framed in one large truss, like a common roof, with two principal rafters, and a collar-beam; each of the rafters becomes a tie for the two small trusses above, which are framed in the manner of a roof, with queen-posts and braces. The lower angles of the principal rafters are braced from the lower queen-posts to the posts. This truss is free from transverse strains in all its parts, except the curve, which supports the arch-stones; and, if well secured at the abutments, an arch of immense weight may be sustained by it.

Figure 3 is the celebrated centre used at Blackfriars Bridge. The names of the timbers are as follows:

A. Timbers which support the centering.

B, C. Upper and lower striking-plates, cased with copper.

D. Wedge between striking-plates, for lowering the centre.

E. Double trussing-pieces, to confine braces.

F. Apron-pieces, to strengthen rib of centre.

G. Bridgings laid on the back of the ribs.

H. Blocks between bridgings, to keep them at equal distances.

I. Small braces, to confine the ribs tight.

K. Iron straps bolted to trussing-pieces and apron-pieces.

L. Ends of beam at the feet of truss-pieces.

M. Principal braces.

The centre used at Westminster Bridge was formed by independent trusses, consisting of two rafters; the intersections all supposed to be halved together, and firmly strapped across the notchings. Double truss-pieces were also used, but for these there was evidently no occasion, as the pressure would be directed to the abutments, or to two opposite points of the arch in the same level.

The annexed plate is a perspective view of the centering of one of the arches of Waterloo Bridge. This magnificent bridge was built under the direction of the late Mr. John Rennie, and is a noble specimen of simplicity of design, skilful arrangement, and solidity of execution. The centre was composed of eight frames or trusses, and, though somewhat complicated, was on the whole a judicious combination; exhibiting rather an excess than a deficiency of strength.

In the erection of Chester Bridge, finished in 1832, an entirely different principle was adopted in the construction and the mode of relieving the centre; it is thus described in the Transactions of the Institution of Civil Engineers. Vol. I.:—

"The centre on which the stupendous arch of Chester new bridge was raised, and which is stated by Mr. Hartley, (the engineer of the bridge,) to have been exclusively designed by Mr. Trubshaw, claims a detailed notice, from the novelty of the principle it was formed on, the efficiency with which it did its work, and the economy that attended its use. The centre consisted of six ribs in width, and the span of the arch was divided into four spaces by means of three nearly equidistant piers of stone built in the river, from which the tim bers spread *fan-like* towards the soffit, so as to take their load *endwise*. The lower extremities of these radiating beams rested in cast-iron shoe-plates on the tops of the piers, and the upper ends were bound together by two thicknesses of 4-inch planking bending round, as nearly as they could be made, in the true curve of the arch. On the rim thus formed, the *lagging*, or covering, which was $4\frac{1}{2}$ inches thick, was supported over each rib by a pair of folding wedges, 15 or 16 inches long, by 10 or 12 inches broad, and tapering about $1\frac{1}{2}$ inch; for every course of arch-stones in the bridge, there were therefore six pairs of striking wedges. The horizontal timber of the centre was only 13 inches deep, and the six ribs were tied together transversely near the top, by thorough bolts of inch iron, but with a view not to weaken and injure the timber more than was absolutely necessary, the least possible of iron was used."

This centre thus differs essentially from any other hitherto employed; each rib, instead of forming one connected piece of frame-work, consisting in this of four independent parts, and hardly any transverse strain has to be resisted. It has also this advantage, that the bearings may be gradually relieved, or tightened at one place, and slackened at another, as may be necessary, because the wedges are in this construction borne by the centre, instead of the centre being borne by the wedges.

In striking centres it is of great advantage to be able to suffer them to rest at any part of the operation; for it is important that the arch in taking its proper bearing do not acquire any sensible degree of velocity, or settle too rapidly. The centre, says Alberti, should always be eased a little as soon as the arch is completed, in order that the arch-stones may take their proper bearings before the mortar becomes hard. If the mortar be suffered to dry before the centre be lowered, the arch will break at the joints in settling, and the connection of the arch will be destroyed. In small centres, the wedges are driven back with mauls, men being stationed at each pair of wedges for that purpose. But in larger works a beam is mounted, as a battering-ram, to drive the wedge-formed blocks back. The French engineers, in removing centres, destroy, by little and little, the ends of the principal supports; a work of difficulty, as well as danger, and which cannot be done with so much regularity in this way as by wedges. *See* Iron Bridge, Stone Bridge, and Suspension Bridge.

Centre, in geometry, a point in a figure or solid, such that if any straight line be supposed to pass through the point until it terminate on both sides of the figure or solid, the line will be bisected. Figures of this property are infinite. Some

of them are the circle, ellipsis, parallelograms, of every species, &c.; and some solids of this nature are the sphere, spheroids, parallelopipeds, &c.

In a circle, the centre is everywhere at an equal distance from the circumference. In a sphere, the centre is everywhere at the same distance from the surface. In the ellipsis, any two straight lines passing through the centre, terminating at each end on the circumference, and making equal angles with either axis, are equal; or the four lines drawn from the centre to the circumference, are equal. The same property applies to the opposite hyperbolas.

Centres of a Door, two pivots, round which the door is made to revolve.

CENTROLINEAD, an instrument for drawing converging lines, when the point of intersection is inaccessible.

CENTRY-GARTH, an old English term for a burial-ground.

CEROFERARIUM, a candlestick used to hold the paschal taper.

CEROMA, the anointing-room in ancient baths and gymnasia.

CESTOPHORI, sculptures of females bearing the cestus, or marriage-girdle.

CESSPOOL. *See* Sesspool.

CHAIN-TIMBER, in brick houses a timber of larger dimensions than common bond, placed in the middle of the height of the story, for strengthening the building; the scantling of chain-timber is 8 inches by 5 inches, or $8\frac{1}{2}$ inches by $5\frac{1}{2}$ inches, viz., equal to the length and breadth of a brick.

CHALCIDICÆ, a large magnificent hall, belonging to a tribunal, or court of justice. Vitruvius employs the term for the auditory of a basilica; and other ancient writers use it for an apartment in which the gods were supposed to sup.

CHALICE, the cup used to contain the wine at the celebration of the eucharist. In early ages, chalices were made of glass, wood, or horn; but in the council of Rheims, A. D. 847, the materials for the chalice were restricted to gold or silver. The rim of the chalice should never turn over.

CHALK, an opaque mineral, of a yellowish white, or rather of a snow colour, of a fine earthy fracture, without lustre, breaking into blunt-edged angular fragments; when contaminated with iron, it has more or less of an ochrey tinge, and stains the fingers; but when pure it is very soft and almost friable, gives a white streak, has a meagre feel, and adheres to the tongue. It effervesces violently with acids; and when mixed with iron becomes harder and heavier: its specific gravity varies from 2·4 to 2·6. It occurs generally in a mass, sometimes disseminated, or investing other minerals.

In a state of purity, it appears to be oomposed only of water, lime, carbonic acid, and a small quantity of alumine. Mr. Kirwan obtained the following analysis:

3	water
53	lime
42	carbonic acid
2	alumine
100	

Chalk occurs in thick beds, nearly horizontal, alternating with thin layers of flint nodules, which are also irregularly dispersed through its substance. It contains a vast quantity of the relics of disorganized marine bodies, and often the hard parts of amphibious and land animals, as the heads and vertebræ of crocodiles, elephants' teeth, &c.

Chalk beds occur frequently in the east and south parts of England, in the north-east of France, in Poland, and in some parts of the Danish islands.

Its uses are numerous; it is employed in walling or vaulting, as building-stone; many of the groins or vaults of our Gothic churches are constructed with it; it is also employed in the composition of mortar, in countries where lime-stone is less abundant; and when well burnt, is found not much inferior to lime-stone.

CHAMBER, (from the Latin *camera*, derived from the Greek *καμαρα*, *a vault*, or *curve*,) a vaulted apartment, a part of a lodging. This term was formerly applied to any room, and sometimes even to a suite of apartments; but in modern times it is used to designate rooms ordinarily intended for sleeping in. The proportion of its horizontal dimensions may be varied, to accommodate different circumstances, which may occur either in the form of a building, or in the disposition of the apartments, from the square to the proportion, of which the breadth is two-thirds of the length; its altitude may be three-fourths of the breadth. The word originally implied a vaulted apartment.

In building bed-chambers, the situation of the bed, as well as of the fire-place, ought to be attended to, as should the disposition of the windows, when they can be shifted without destroying the symmetry of the exterior. If the bed and fire-place be opposite to each other, the fire-place may be in the middle of its own side; but if it should be found necessary to have the bed on the same side of the room with the fire-place, on account of doors or windows, or both, then the chimney ought to be placed in the middle of the remaining distance between the bed and the wall, the bed being supposed to stand at one extremity. The situation of doors may be the same as in other apartments; passage-doors should be within about two feet of the angle of the room, on whatever side they are made; and may either be on the same side with the fire-place, or on the opposite side to the fire-place, or in the return side, opposite to the window, next to the farther corner from the fire-side of the room.

The bed ought to be so placed as to be out of the current of air, which usually rushes from the door to the fire-place.

The most eligible figure of chambers, for furniture, is the rectangle; though sometimes the circle, ellipsis, or octagon, may be allowed to some particular room, for the sake of variety. Besides passage-doors, it is convenient for chambers to communicate with each other, or with a dressing-room.

Chamber of a Lock, in inland navigation, the space between the gates, in which a boat rises and sinks from one level to another, in order to pass the lock.

Chamber-Story, a story of a house appropriated to bedrooms. In good houses it should never be less than 10 feet high; and in mansions 12, or even 15 feet high. Chambers should not be too high, because it is difficult to warm them; nor too low, as it is prejudicial to the health.

CHAMBERS, SIR WILLIAM, a distinguished architect, is said to have derived his descent from the ancient family of Chalmers, in Scotland, barons of Tartas, in France. He was born, however, at Stockholm, in Sweden, where his father had resided for many years, in order to prosecute certain claims he had on the government of that country. When a very young man, he made a voyage to China, as supercargo in the service of the Swedish East India Company, and probably thus acquired his taste for the Asiatic style of ornament. At the very early age of eighteen, we find him established in London as an architect and draughtsman, in which capacities he soon acquired considerable reputation; and obtaining an introduction to Lord Bute, shortly afterwards was appointed

through that nobleman's influence drawing-master to the Prince of Wales, afterwards George III.

He was employed, soon after the accession of George III., to lay out the gardens at Kew, and there displayed, without restraint, his predilection for the Chinese style, both of architecture and gardening, decorating the royal gardens with numerous temples, pagodas, and other Asiatic buildings. Being patronized by the King and Princess-dowager, he was employed as architect to the most considerable buildings of the day; and was also appointed Surveyor-General to the Board of Works in Somerset House, a situation worth at least two thousand pounds a year. Sir William died in 1796, leaving a large fortune. As an architect, although his taste was fantastic, he frequently displayed a certain grandeur in his designs, and in the disposition of interior arrangements particularly, showed considerable ingenuity and practical ability. His *chef-d'œuvres* are his staircases, particularly that in the Italian villa he erected for the Earl of Besborough, at Roehampton; and also those at Lord Gower's and the Royal Antiquarian Society's.

In the time of Sir W. Chambers, pure Greek architecture was only beginning to be known in England; and at first its introduction was not much favoured. The indiscriminate adoption of Greek models for public buildings in London has filled the metropolis with structures quite unsuited in external form to improve the appearance of a large city, and often ill adapted in their internal arrangements to the purposes for which they are designed. Instead of large masses and lofty buildings, the streets of London are crowded with mean porticos and pigmy pillars, attached to edifices of so little elevation, and so much cut up into small parts, as to suffer by comparison even with many of the adjoining houses.

The street-front of Somerset House, Chambers's best work, is, in all respects, better adapted to a great city, than the Greek models which are now too generally adopted; and the river-front forms one of the boldest architectural objects in the metropolis, particularly when beheld from the water. Its extent and elevation, and the majestic breadth and range of its terrace, give it an air of grandeur exceedingly striking and imposing.

The works published by Sir William Chambers were— *A Treatise on Civil Architecture*, of which a new edition, by Joseph Gwilt, Esq., F. S. A., appeared in 1824. *Plans, Elevations, Sections and Perspective Views of the Gardens of Kew; Chinese Designs;* and *Chinese Gardening.* His *Treatise on Civil Architecture*, though prejudiced against Grecian architecture in favour of the Roman, is an excellent work.

CHAMBRANLE, the border of stone, or the wooden frame, surrounding the three sides of a door, window, or chimney; the head of the chambranle is called the *traverse*, and the two sides, the *ascendants.*

When the chambranle is plain, it is called *a band, case,* or *frame.* In an ordinary door, it is called the *door-case;* in a window, *the window-frame;* in the latter case, it comprehends also the sill. When the chambranle is moulded with one or more faces, and bordered outwardly with one or several mouldings, it is called *an architrave;* though it should rather be said to be *architrave-moulded*, being only an imitation of that division of the entablature of an order.

CHAMFERED, *Rustic.* *See* RUSTIC.

CHAMFERET, a half scotia, being a kind of furrow, or gutter, on a column; called also *strix*, and *stria.*

CHAMFERING, *καμπτειν, to bend*, the act of cutting the edge of anything, which was originally right-angled, aslope, or bevel; so that when placed in its destined situation, the plane formed by this cutting may be inclined to the horizon, while the other parts are perpendicular and parallel to it.

A chamfer differs from a splay in being smaller, and in cutting off an equal portion from either side. In Gothic architecture chamfers are very frequent, and are often ornamented with mouldings and foliage at their terminations.

CHAMP, a flat surface, the ground of relieved sculpture, or engraving.

CHAMPAIN LINE, a conjunction of straight lines, forming indentations similar to the projecting parts; the sides of each ascending part, which are also the sides of the alternate indentations, being parallel to each other; the bottom of each indentation being formed of three internal angles, and the top of each projecting part of three external angles; each ascendant and each indentation being shaped alike on both sides; that is, the corresponding angles and lines, whether of the ascendants, or in the depressions, being equal.

CHANCEL, that part of a church which is appropriated to the clergy and others officiating in the public services.

The term comes from the Latin, *cancellus*, which, in the lower Latin, is used in the same sense, from *cancelli*, lattices, or cross-bars, which anciently partitioned the chancel from the other part of the church.

Externally, the chancel is distinguished as a projection at the east end, of smaller dimensions than the nave, and without aisles; so that when the body of the church is accompanied by aisles, it is very readily recognized, and in other cases by its proportionate dimensions. Sometimes, however, the chancel is of the same size and height as the nave, and the aisles are continued to its eastern extremity; but even in this case the division may be shown by means of a belfry on the apex of the roof at that spot or by some other such method; in some instances there is no distinction externally. Internally the chancel is usually separated from the nave by a lofty arch, in the spandrels above which is often a picture of the Last Judgment; a further separation is effected by an ornamental screen of wood or stone, more frequently of the former, panelled and pierced in open tracery, surmounting which was in former times, the rood-loft, or gallery in which the rood, or large crucifix, accompanied by the images of the blessed Virgin and St. John, was placed, facing the west end of the church. Here the level of the flooring was raised by one or more steps, and again before you arrive at the platform on which stood the altar; in one or two cases the chancel is depressed below the level of the nave, but these are purely exceptions.

When the aisles of the nave are continued eastward, the only division consists of the screen and steps; but the distinction will be effected by some difference in the roof, or by the superior quality of the decoration. In such cases the aisles are partitioned off from the chancel by other screens or parcloses.

The chancel is lighted by the east window, which should be the most important in the building, and by two or more in the north and south walls, according to its length. There is a door in one of the side-walls, towards the east end, for the priest, leading into the vestry, or forming his entrance into the church. The roof is of a more elaborate character than that in other parts of the structure, as indeed are all the enrichments. The floor was often covered with encaustic tiles, with devices of various colours painted on their surface, while the aisles in the body of the edifice were paved with tiles of a plainer description; the whole of the walls were sometimes decorated with colour and rich hangings, a method which has of late been adopted with success in one or two churches in London.

In the centre of the eastern wall was the altar, and on the

south of it the piscina, usually formed by a recess, in the eastern extremity of the south wall, and used to wash the sacred vessels, to contain which, when not in use, was provided an aumbry or cupboard near the piscina, and taken out of the thickness of the south or north wall, furnished with a door and means of securing it. Adjacent to the piscina are sometimes found, especially in the larger churches, seats for the officiating priests. These sedilla, as they are termed, consisted of stone or wooden seats, varying in number from one to five, the more usual number being three, raised in gradation one above the other, according to the rank of the clergy who were to occupy them; when of stone, they are more generally cut out of the thickness of the wall; when of wood, they may be movable. Westward of these, disposed on each side of the chancel, are the seats for the choristers, consisting of two or three rows, one in front of the other and a little below it. Occasionally these seats are returned in front of the rood screen, and in that case they always face eastward toward the altar.

In the north wall of some chancels is found an arched recess, which sometimes contained a stone tomb, occasionally that of the founder; this was the holy sepulchre on which the ceremonies commemorative of our Lord's burial and resurrection were celebrated at the season of Easter. Where there is no sepulchre, a movable wooden structure was employed for the purpose.

The principal feature of the chancel is the altar. This is an elevated table of an oblong shape, constructed of either wood or stone; in the first ages of the church, up to the fifth century, they were generally made of the former material, though stone was recommended by Pope Sylvester, early in the fourth century. The council of Hippo forbade the use of wood, as did also that of Epone, in France, at the commencement of the sixth century, from which period they have been made of stone. Stone altars were disused in England at the Reformation, and so few survived the turmoils of this period, and of the succeeding rebellion, that we have scarcely an entire example left; those in the chantries and side-chapels are almost the only ones that escaped destruction. The high altar of Arundel church, Sussex, which was preserved by being enclosed in wood, will give us a fair idea of their form and construction. It consists of a slab 12 feet six inches long, by 4 feet wide, and $2\frac{1}{2}$ inches in thickness, supported on a solid stone 3 feet 6 inches in height, and quite plain; in some cases, however, the front and sides were carved in panels and various devices, and richly coloured. Sometimes the slab is supported on stone legs, and sometimes on brackets, as at Broughton Castle, Oxford; it was generally marked on its upper surface with five crosses in recession, one in the centre, and one in each corner, representing the five wounds of our Lord. In the church of Porlock, Somersetshire, the crosses do not appear on the slab, but are found in the centre panel in the face of the supporting masonry.

That part of the east wall immediately above the altar is frequently ornamented with a reredos of tabernacle work, or a series of enriched arches; sometimes this space is occupied by a triptych, or painting of three compartments, often representing the crucifixion.

"Pertaining to the high altar," says Mr. Bloxham, in his valuable little manual, "which was covered with a frontal and cloths, and anciently enclosed at the sides, with curtains suspended on rods of iron projecting from the wall, was a crucifix, which succeeded to the simple cross placed on the altars of the Anglo-Saxon churches; a pair of candlesticks, generally with spikes instead of sockets, on which lights or tapers were fixed; a pix, in which the host was kept reserved for the sick; a pair of cruets, of metal, in which were contained the wine and water preparatory to their admixture in the eucharistic cup; a sacring bell; a pax table, of silver or other metal, for the kiss of peace, which took place shortly before the host was received in communion; a stoup, or stok, of metal, with a sprinkle for holy water; a censer, or thurible; and a ship—a vessel so called—to hold frankincense; a chrismatory, an offering basin, a basin which was used when the priest washed his hands; and a chalice and paten."

Another part of the furniture of the chancel is the credence-table, or table of prothesis, on which the elements were placed previous to consecration, usually situate on the north side of the altar. This is of much smaller dimensions than the altar, sometimes of stone richly panelled, as at the church of Holy Cross, near Winchester, and Fyfield, Berks, where it is in shape semi-octagonal; they were sometimes also of wood, a specimen of which is pointed out at Chipping-Warden, Northamptonshire, the date of which is A. D. 1627. The credence is very frequently found in the form of a shelf above the piscina, and under the same niche and canopy.

We must not forget to mention the lettern, or desk, from whence the lessons were read, which was placed at the western end of the chancel; it was generally of brass, sometimes in the shape of an eagle with expanded wings, and sometimes forming a sloping desk, with the slope on one or two sides, in all cases supported on an ornamental stem. Eastward of this, immediately in front of the altar-steps, was the fald-stool, a low, sloping desk, at which the priest knelt at the Litany.

The chancels of our old churches vary so much in size and proportion, that it is impossible to lay down any rule by which their dimensions may be determined; we always find them, however, of sufficient space to form a prominent feature in the building; sometimes they are as long, or longer than the nave, but this practice we would not recommend for adoption. It may be laid down as a general rule, that the chancel be well defined and fully developed, yet not of so great length as to prevent the voice of the celebrant being heard throughout the nave; on an average, we may give the length of 30 feet as a standard for most modern churches, but of course this dimension will vary with the size and width of the church. The materials and workmanship in this part of the edifice should always be of the very best description, and the ornamentation more rich and frequent; care must be taken to avoid the use of any decoration except such as is of a strictly religious character, and adapted to its particular situation: all meretricious ornament should be at once discarded; severity is wanted, not display.

CHANDELIER, a candlestick, lamp, &c. suspended by a chain, rope, or bracket.

CHANDRY, a room where candles and other lights are kept.

CHANNEL, a canal, or long gutter, sunk within the surface of a body

CHANNEL OF THE LARMIER, a hollow soffit, or canal, under the corona, which forms the pendent on the front. *See* BEAK.

CHANNEL OF THE VOLUTE, in the Ionic capital, is the hollow spiral, sinking between the fillets. *See* CANAL OF THE IONIC VOLUTE.

CHANNEL STONES, in paving, are those prepared for gutters or channels, for collecting and turning off the rain-water with a current.

CHANTLATE, in building, a piece of wood fastened near the ends of the rafters, and projecting beyond the wall, to support two or three rows of tiles, so placed as to prevent the rain-water from trickling down the walls.

CHANTRY, or CHAUNTRY, was anciently a church or chapel, endowed with lands, or other yearly revenues, for the mainte-

nance of one or more priests, daily saying or singing mass for the souls of the donors, and such others as they appointed.

Chantries, are also small chapels attached to a church, and are sometimes external additions to the church; but more frequently, especially in cathedrals and the larger churches, erections within it; they are separated off from the body of the church by screens of open work surrounding and enclosing the tombs of the founders, and are usually provided with an altar at the east, with its appendages, such as piscina, aumbry, &c. Many beautiful specimens are to be found in our cathedral and abbey churches, and amongst the most costly may be enumerated those of Henry V. and Henry VII. at Westminster, the latter of which is, as is well known, of great size and magnificence; of Edward IV. at Windsor; of Edward II. at Gloucester; and of Bishops Waynfleet, Beaufort, and Wykeham at Winchester.

CHAPEL, a small detached building for divine service, subordinate to, and usually dependent on, the parish church, from which it is distinguished by the fewer privileges belonging to it, such as having no proper priest attached, or being deprived of the power of having baptism administered within it.

Chapel, is also a building adjoined to a church, as a part thereof, having only a desk, &c. to read prayers in, and, in the Romish churches, an altar, &c. to celebrate mass on; but without any baptistry or font.

The eighteen chapels on the sides of King's College chapel, Cambridge, are formed between the buttresses; most of them were originally provided with altars: those on the south side of this magnificent building, are appropriated to the college library.

Previous to the Reformation, nearly all castles, palaces, mansions, and religious establishments, were provided with private chapels. These were either detached buildings, or portions of the entire edifice constructed and set apart for sacred purposes.

Chapel, also denotes the deep recesses made in the walls of ancient edifices, and is of a similar signification to what is otherwise called *exhedræ*, by Vitruvius; thus the Roman Pantheon has seven chapels in its circumference, the entry corresponding to what otherwise might have been the eighth; and the sides of the courts of the great temple at Balbec are full of chapels, or *exhedræ*. Those of the rectangular court of this temple, and those of the Pantheon, are alternated with circular and rectangular plans, and most elegantly decorated with columns in the front towards the interior. The semicircular recess at the end of the basilica, and at the end of our most ancient churches, is often denominated *chapel*. Smaller recesses in ancient edifices, for containing statues, are denominated *shrines*, or *niches*.

CHAPITER, the same as Capital, which see.

Chapiters with Mouldings, are those without foliage, or other ornaments, as the Tuscan and Doric capitals.

Chapiters with Sculptures, are those that are adorned with foliage, and other carved ornaments; the finest yet invented is the Corinthian capital.

CHAPLET, a small ornament cut into olives, beads, &c.; a sort of fillet.

CHAPTER-HOUSE (from *capitulum*), a place belonging to a cathedral, or collegiate church, wherein the assemblies of the clergy were held.

The greater number of chapter-houses were connected with the cloisters of the church to which they belonged, by which means they were approached from the church; but, at Wells, York, and Lichfield, they are adjacent to the north transept, in the first case being considerably elevated above the level of the church; they are seldom found westward of the transept. The earlier of these edifices, dating of the eleventh and twelfth centuries, are in plan parallelogramic, terminating sometimes toward the east in a semicircle, as at Durham Cathedral; at later periods we find them octangular or polygonal, while that of Worcester is circular internally, with ten sides on the exterior. In elevation the walls are supported by buttresses—that of Lincoln with flying buttresses—with one or more windows between each pair, the whole being covered in the later instances, with a very high-pitched roof gathering from each side of the building, and terminating in a point at its apex. Below the windows, in the interior, runs a continuous seat or bench-table, backed with a series of niches or arcades, and at the east end, facing the entrance, stand three stone seats, usually of greater elevation than the rest, appropriated to the superior members of the chapter. The ceiling is more frequently vaulted. Among the earlier specimens may be enumerated Durham, probably the oldest, parallelogramic, with circular east end; Gloucester, Bristol, Oxford, Chester, Canterbury, and Exeter, all of which are rectangular. The first variation seems to have been at Worcester, which is circular within and decagonal without; the vaulting of the interior being supported by a central pillar and brackets in the side-walls. Of the remainder, Lincoln has ten sides, the vaulting supported by a central column and flying buttresses, which last appendage forms its peculiarity; Wells, Lichfield, Salisbury, and York, only eight sides, the vaulting sustained, as in the previous examples, that of York only excepted, where the vaulting is carried across the building in a single span of forty-seven feet. Wells chapter-house is erected over a crypt, a peculiarity which it shares with that of Westminster; that of Lichfield, although octangular, has two of its opposite sides of longer dimensions than the others, in which respect it is perfectly unique; while that of Salisbury is perhaps of all specimens the most beautiful.

The subjoined List of Chapter-Houses in England, (from Britton's valuable works,) may be found useful.

	Length. Int.	Length. Ext.	Breadth. Int.	Height. Ext.	Height. Int.	
						Rectangular.
Bristol	43ft.	53ft.	25ft.	36ft.	26ft.	Date 1142; adjoins S. transept; approached from cloister by a vestibule; vaulted roof.
Canterbury	87	99	35	45	52	N. of transept; entrance from cloister; vaulted roof with wood and tracery; large E. and W. windows.
Gloucester	68	77	35	44		Very lofty entrance from cloister; arched roof.
Durham	78	90	36	45		Date 1133; semicircular end; taken down.
Chester	50	58	26	36	36	
Oxford	54	64	24	34		Temp. Henry II.; S. of transept; entrance from cloister.
Exeter	55	62	28	38	50	Lower part about 1230—upper part 1427.
Winchester	88					One side remains; and joins S. transept with slyp between.
Llandaff	23	27	21	26		Early pointed.
						Octagonal, Polygonal, &c.
Worcester	55	65	55	65		About 1150; separated from S. transept by passage.
Lincoln	62	70	62	70	42	Before 1200; 140 feet diameter including buttresses.
Lichfield	45	54	28	36		About 1200; large vestibule.
Westminster	58	66	58	66		Temp. Henry III.: octagon; central column; over crypt.
Wells	55	65	55	65	42	Over crypt; small vestibule.
Hereford	45		45			Decagon; fragment remaining.
Salisbury	53	58	53	58	52	S. of transept; entered from cloister; vestibule; about 1260.
York	57	70	57	70		Connected with N. transept by vestibule; vaulted roof, of wood.

CHAPTREL, from *chapiter*, the capitals of pillars and pilasters, which support arches, commonly called impost. *See* IMPOST.

CHARGED, a term in architecture, implying that one member of an edifice is sustained by another; in which case, the latter is said to be *charged* with the former. Thus, a frieze, or other surface, when ornamented, is said to be *charged* with the ornament; but when the ornament is too abundant, it is said to be *over-charged;* a column supporting an entablature is said to be *charged* with the entablature.

CHAR or CHARE; on old term equivalent to the word hewn or wrought; thus charred stone is hewn stone, as distinguished from rubble.

CHARNEL-HOUSE (Latin, *caro-carnis*, flesh) a vaulted apartment, beneath or adjoining a church, in which human bones are deposited.

CHARTOPHYLACIUM (Greek, *χαρτης*, *paper*, and *φυλασσειν*, *to guard*), the place where records were kept.

CHASE-MORTISE, or PULLEY-MORTISE, a long mortise cut lengthwise in one of a pair of parallel timbers, for inserting the one end of a transverse timber, by making the transverse to revolve round a centre at the other end, which is fixed into the other parallel timber. This is applicable to ceiling-joists, where the binding-joists are the parallel timbers first fixed, and the ceiling-joists are the transverse joints.

CHAUNTRY. *See* CHANTRY.

CHECKERED, or CHEQUERED, a surface is said to be checkered, when it is divided into a number of equal contiguous parallelograms, alternately coloured. The term is sometimes applied to reticulated masonry. *See* RETICULATED and MASONRY.

CHEEKS among mechanics, are those pieces of a machine which form corresponding sides, or which are double and alike: two equal and similar parts, generally placed parallel to each other.

CHEEKS OF A MORTISE, the two solid parts upon the sides of the mortise. The thickness of each cheek should never be less than that of the mortise, except mouldings on the styles require it to be otherwise.

CHEESE-ROOM, a room appropriated for the reception of cheeses, after they are made. Rooms of this description should be lined round the walls, and fitted up with shelves, having one or more stages, according to the size of the room, and proper gangways for commodious passages. In places where much cheese is manufactured, the dairy-room may be placed below, the shelf-room immediately above, and lofts over the shelf-room, with trap-doors through each floor. This will save much carriage, and be very advantageous for the drying of cheeses.

CHEQUERS, in masonry, stones in the facings of walls, having all their joints continued in straight lines, without interruption, or breaking joints. Walls constructed in this manner, are of the very worst description, particularly when the joints are made horizontal and vertical. Those consisting of diagonal joints, or joints inclined to the horizon, were used by the Romans. *See* MASONRY and RETICULATED.

CHEST, in bridge-building, the same as CAISSON, which see.

CHEVET (French), the eastern end of a church, when of a circular or polygonal form: equivalent to APSIS, which see.

CHEVRON-WORK, a zig-zag ornament, somtimes called the dancette, usual in the archivolts of Saxon and Norman arches. The outline of chevron-work is a conjunction of right lines, of equal lengths, alternately disposed, so as to form exterior and interior angles, with the exterior angles equal to the interior ones; and all the angular points in the same straight line, or in the same curve line, when they are the ornaments of arches.

The lines of chevron-work are similar to what is denominated *indented* lines in heraldry, and not unlike the indentations or teeth of a joiner's hand-saw; the only difference being the greater inclination of the teeth on one side than on the other; but in chevron-work, they are equally inclined to the line passing through the angular points.

CHIMNEY (from the French, *cheminée*, derived from the Latin, *caminus*, borrowed from the Greek, *καμινος*, *a chimney*, from *καιω*, *I burn*), that part of a building wherein the fire is contained, and through which the smoke passes away.

The chimney generally consists of an opening in, and through a wall, upwards, beginning at the floor on one side of an apartment, and ascending within the thickness of the wall, till it comes in contact with the atmosphere, above the roof of the building.

The parts of the chimney, and of the wall in which it is inserted, are denominated as follows:

The opening, facing the room, being the place where the fire is put, is termed *the fire-place.*

The stone, marble, or plate, under the fire-place, is called *the hearth.*

That on the same level, before the fire-place, is called *the slab.*

The vertical sides of the opening, at the extremities of the hearth, forming also a part of the face of the wall of the apartment, are called *jambs.*

The head of the fire-place, resting at its extremities on the jambs, presenting one face vertical in the surface of the wall, and another towards the hearth, is called the *mantel.*

The whole hollow, from the fire-place, to the top of the wall, is denominated *the funnel.*

That part of the funnel which continually contracts, or diminishes in its horizontal dimensions, as it ascends, is termed *the gathering*, or by some, *the gathering of the wings.*

The long narrow prismatic tube, over the gathering, or that part of the funnel which has its horizontal dimensions the same throughout the altitude of the chimney, is called *the flue.*

That part between the gathering and flue, is denominated *the throat.*

That part of the wall which faces the apartment, and forms the side of the funnel parallel thereto, or that part of the wall which forms the sides of the funnels of several fire-places, is called *the breast.*

In an outside wall, the side of the funnel opposite the breast, is called *the back.*

When there are two or more chimneys in the same wall, the divisions between them, or the solid parts of brick, stone, or metal, are called *withs.* A gable, partition, or party-wall, containing a collection of chimneys, is termed *a stack of chimneys.*

The turret above the roof, for discharging the smoke into the air, of one, two, or a collection of chimneys, is called *the chimney-shaft;* and the horizontal surface, or the upper part of the said shaft, *the chimney-top.*

When the parallel sides of the jambs are faced with stone, marble, or metal, so as to form four obtuse angles, viz., two internally with the back, and two externally with the breast or side of the apartment, making the horizontal dimension of the outside of the fire-place of greater extension than that of the back, the facings are called *covings.*

In stone walls of ordinary buildings, the most common dimensions for the sections of the flues of sitting-rooms are from twelve to fourteen inches square, and for the brick-work, nine by fourteen inches. The section of the flue must,

however, be proportioned to the section of the fire, which, when found necessary to vary from ordinary cases, should be equal to the said horizontal section of the fire, or nearly so.

To prevent smoke, the chimney ought to be so constructed, that a current of air may pass immediately over the fire, so as to be rarefied in its passage, and not to pass entirely through the fire, as many have erroneously imagined. For this purpose, the throat should be so near to the fire, as to prevent the cold air from passing over it, and its horizontal dimension in the thickness of the wall should not exceed four inches and a half, or five inches at most.

This contraction is to be formed by facing up the back, and bevelling the covings, so that no cold air may be admitted by the ends of the fire; by thus obliging the overplus above the quantity necessary to produce combustion, to pass over the fire, it becomes so heated, as to consume the smoke in part, and to drive the remaining portion before it, with celerity and violence.

The covings are in general placed at an angle of one hundred and thirty-five degrees with the back and breast, and should be made to form an abrupt plane on their top, so as to break the current of a sudden gust of wind.

The greater the quantity of rarefied air that passes up the flue, and in general the higher the chimney, the more celerity and force will it ascend with. The flue ought, therefore, to be carried as high as conveniency will admit.

To prevent the absorption of heat, the back and covings should be constructed of white materials, or, if not, they should be covered with plaster, and whitened as often as they become black, and thus they will reflect a greater quantity of heat.

Most metals absorb the heat, and are therefore unfavourable for this purpose.

The back and covings are most conveniently put up after the house is built. The introduction and general use of "registers," has obviated any difficulty in this respect; they form a great improvement on the old method.

Some of the principles in the construction of chimneys are very well ascertained, others are not easily discovered till tried.

The tops of flues should not have such wide apertures, as to permit a greater quantity of air to rush down the chimney, and counteract the force of the ascending rarefied steam.

Smoky chimneys are frequently occasioned by the situation of doors in a room, the grate being placed too low, or the mantle too high. There are many cases in which it is not easy to discover the cause; but if once known, it may be easily removed.

Flues with circular sections are, with some reason, supposed to be more favourable for the venting of smoke, than those whose sections are square or rectangular.

There is much difference of opinion as to the origin of chimneys. They do not seem to have been in use among the classics, as they are not found, as Winklemann informs us, amongst the ruins of Herculaneum, although coals have been discovered in some of the rooms, from which he conjectures that the Romans used charcoal fires; Mr. Lysons, however, describes a fire-place, which he found in one of the rooms of the Roman villa at Bignor, in Sussex. There does not seem to be any evidence of the use of chimneys in England before the twelfth century, when we meet with them in the castles of Rochester, Hedingham, &c., also in a Norman house at Winwall in Norfolk, in these cases, however, the flue is carried up only a short distance in the thickness of the wall, and is then turned out at the back, the apertures being small oblong holes. Shortly afterwards we meet with flues carried up the whole height of the wall, as at the castles of Conisborough, Newcastle, Sherbourne, &c., as also at Christ Church, Hants. At this period the shafts were carried up to a considerable height, and are generally circular; in after times the forms varied considerably, and terminated frequently with a spire, pinnacle, or gable, with apertures of ornamental forms in the sides underneath for the escape of the smoke. During the fourteenth century the shafts were very short, and of great variety of forms. In the fifteenth, the shafts were more usually octangular, sometimes square, with the aperture at the top; at the latter end of this century we find clustered shafts, which afterwards became so common in Elizabethan buildings. These clustered chimneys are most frequently of brick, variously and elaborately ornamented all the way up the shaft, and indeed form a very prominent and beautiful feature in buildings of this period. Fine specimens of the kind are to be seen at Hampton Court Palace, Eton College, East Basham Hall, Norfolk, and all the larger buildings of the Elizabethan style; examples in stone, though more rare, exist at Bodiam Castle, Sussex, and on houses at South Petherton and Lambrook, Somersetshire.

CHINESE ARCHITECTURE, that which is used by the inhabitants of China, and employed in their temples and other edifices. It would be very difficult to give such a definition as should point out the species of architecture practised by the Chinese; we must therefore have recourse to the descriptions of those who have drawn and actually measured their edifices with care. To the attainment of this, our materials are few. Sir William Chambers is the only author we are acquainted with, who has given representations of Chinese edifices from measurement, and who was able to discriminate, as an architect, those characteristic forms by which it is distinguished from other species of architecture, and to mark out its peculiar features. In his preface he observes:

"To praise too much or too little, are two excesses which it is equally difficult to avoid. The knowledge of the Chinese, their policy and skill in the arts, have been praised without bounds; and the excessive encomiums that have been given them, show with what force novelty strikes us, and how natural it is to pass from esteem to admiration.

"I am far from joining in the over-strained eulogies of the Chinese. If I find among them wisdom and sublimity, it is only when I compare them with the people that surround them; nor shall I put them on a parallel with the inhabitants, either ancient or modern, of our quarter of the world. At the same time, we must acknowledge, that our attention is due to this distinct and singular race of men, who, separated from the polished nations of the world, have, without any model to assist them, been able of themselves to mature the sciences and invent the arts.

"Everything that regards a people so extraordinary, has a claim to our attention; but though we are pretty well instructed in most things respecting them, we are very little so in their architecture. Many descriptions that have been hitherto given us of their edifices, are unintelligible, the best give but indistinct and confused ideas of them, and none of the drawings deserve the least attention.

"Those which I at present offer to the public, are drawn from sketches and measures that I took at Canton some years ago. I took them merely to satisfy my own curiosity. I had not the least intention to publish them; and they would not have appeared at present, had I not yielded to the solicitations of several amateurs of the fine arts. They have thought them worthy of the attention of the public, and that they might be useful in stopping the course of those extravagant productions, that appear every day, under the name of Chinese; although the most part of them are pure works of

fancy, and the rest only mutilated representations that have been copied from porcelain and various paintings on paper.

"What is really Chinese, has at least the merit of being original. Seldom, or never, have this people copied or imitated the inventions of other nations. Our most authentic accounts agree on this point. Their government, their customs, their dress, and almost everything else, have continued unchanged for thousands of years. Their architecture has, besides, a remarkable resemblance to that of the ancients; and this is the more surprising, as there is not the least probability that the one has been borrowed from the other.

"In the Chinese architecture, as well as that of the ancients, the general form of almost all their compositions tends to that of the pyramid. In both, the columns serve for supports, and in both the columns have diminutions and bases, which in many respects are similar. The entrelas, so common in ancient edifices, are often seen in those of the Chinese. The *ting* of the Chinese differs but little from the *peripteron* of the Greeks. The atrium, and the monopterous and prostyle temples, have a considerable resemblance to some among the Chinese; and the manner in which they construct their walls is on the same principle with the revinctum and emplecton, described by Vitruvius. There is, besides, a great resemblance between the utensils of the ancients and the Chinese; both are composed of similar parts, combined in a similar manner.

"It is by no means my intention, in publishing a book on Chinese architecture, to bring in vogue a taste so inferior to the ancient, and so little suited to our climate. But the architecture of one of the most extraordinary people of the universe offers an interesting phenomena to a lover of the fine arts; and an architect ought to be acquainted with so singular a manner of building. The knowledge of it is, at least, curious; it may even be useful on particular occasions. An architect is sometimes asked for Chinese compositions; and, in certain cases, they may be judicious. For though, in general, the architecture of China is not suitable to Europe, yet, in parks and gardens, where the extent demands a great variety, or in large palaces that contain numerous enfilades of apartments, I do not think that it would be improper to decorate some of the most inconsiderable pieces in the Chinese taste. Variety never fails to please, and novelty, when there is nothing disagreeable or shocking in it, often holds the place of beauty. At the time that the Greek architecture prevailed the most among the Romans, history informs us that Adrian, who was himself an architect, erected, at his country seat at Tivoli, several buildings in the style of the Egyptians and some other nations.

"The grandeur or the richness of the materials is not the distinguishing characteristic of the Chinese edifices. But there is a singularity in their manner, a justness in their proportion, a simplicity, sometimes even a beauty, in their form, that deserves our attention. I look upon them as gewgaws in architecture; and if singularity, prettiness, or neatness in the work, give a place to trifles in the cabinets of the curious, we may likewise introduce Chinese buildings among compositions of a better kind."

Sir William has above noticed the pyramidal form of Chinese structures, and indeed the similarity of the architecture of this extraordinary people with that of all the early nations in this respect, is worthy of notice; yet the resemblance of their buildings to tents is even more remarkable, so striking indeed is it, that some travellers have compared their cities to vast encampments. The Chinese, like all the Tartar tribes, were a nomadic race; and doubtless in their wanderings were accustomed to employ tents, coverings portable and readily erected, to defend them from the heat and inclemencies of the weather, and when they settled permanently, preserved the same form in the construction of their dwellings. The construction of their buildings is indeed remarkable, and tends to confirm the foregoing statement; for, as Mr. Gwilt remarks, "though the carpentry of which they are raised has for ages been subjected to the same forms, when we consider the natural march of human invention, especially in cases of necessity, we cannot believe that, in a country where the primitive construction was of timber, the coverings of dwellings would have been at once so simple and so light. Their framing seems as though prepared merely for a canvas covering. Again, we have, if more were wanting, another proof, in the posts employed for the support of their roofs. On them we find nothing resting analogous to the architecture for receiving and supporting the upper timbers of the carpentry; on the contrary, the roof projects over and beyond the posts or columns, whose upper extremities are hidden by the eaves, thus superseding the use of a capital. A canvas covering requires but a slender support, hence lightness is a leading feature in the edifices of China; whilst other materials than those which formed tents have been substituted for them, the forms of the original type have been preserved, making this lightness the more singular, inasmuch as the slightest analogy between those of the original and the copy is imperceptible. This change of material prevents in the copy the appearance of solidity, and seems a defect in the style, unless we refer to the type."

Another peculiarity which strikes the European upon first beholding a Chinese city, is the gaiety of their buildings, arising from the prevalent application of colour. Their roofs are composed of coloured and glazed tiles, their floors of variegated stone or marble, and their porticos not only coloured with the brightest tints, but also profusely varnished, all uniting to produce an effect altogether different from that presented by all other styles.

Sir William then proceeds with the work as follows:

"*The Temples of the Chinese.*—A great number of temples are to be seen at Canton. The Europeans call them commonly *pagodas*. Many of these temples are extremely small, and consist only of one single apartment. Some others have a court, surrounded with galleries, at the end of which is a *ting*, where the idols are placed; and there are a few, which are composed of many courts, surrounded with galleries. The bonzes, or priests, have cells there, and the idols different halls. These are properly convents, and some of them have a great number of bonzes, who are attached to them by particular vows, and who live in them in the exact observance of certain rules.

"The most considerable of these pagodas is that of Honang, in the southern suburb, *Plate* I., *Figure* 1. It occupies a great extent of ground; and accordingly it contains, besides the temples of the idols, apartments for two hundred bonzes, hospitals for many animals, a large kitchen-garden, and a burying-ground. The priests and animals are buried promiscuously, and equally honoured by monuments and epitaphs.

"The first object that presents itself, is a court of considerable extent. In it are three rows of trees, which lead to an open vestibule, A, to which the ascent is by a few steps, B. From this first vestibule, we pass to a second, C, wherein are four colossal figures in stucco; they are seated, and hold in their hands divers emblems. This vestibule opens into another large court, D, surrounded by colonnades, E, and cells for the bonzes, F. Four pavilions, G, are placed in it, on socles. These pavilions are the temples; the two stories, of which they are composed, are filled with idols, and the bonzes perform their religious service in them. At the four corners of the court are four other pavilions, H, where the superior

bonzes have their apartments; and under these columns, between the cells, are four halls, I. occupied by idols.

"On each side of this great court are two other small courts, K, surrounded with buildings. One is for the kitchen, L, and for the refectories, M; the other serves for the hospitals, N, of which we shall speak.

"I do not give the elevation of the great court, because it could not have the suitable dimensions, without occupying at least three plates. The pavilions are of different forms; but they all present a very similar appearance, and the proportions between the colonnades and the pavilions are also nearly the same. The boxes or cells of the bonzes are of stone, they are very small, and admit no light but by the door. The bodies of the pavilions are built of the same material, and the columns which surround them, as well as the colonnades, are of wood, having bases of marble. All the buildings are covered with tiles, made of a coarse kind of porcelain, painted green, and varnished.

"The same plan is observed in all the temples of this kind; and by detaching from them the three pavilions that occupy the middle of the great court, we may form an idea of the manner in which Chinese edifices of great extent are planned, or laid out. The imperial palace, those of the princes of the blood, the palaces of the mandarins, the Kong Quaens, or colleges of letters, are all disposed nearly in the same manner; the principal difference consists in the number and extent of the courts.

"The edifices that the Chinese make use of for religious purposes, are not, like those of the ancients, of any appropriate form; the particular kind of construction that they call *ting*, or *kong*, enters indifferently into all kinds of edifices, they are seen in almost all temples, in all palaces, above the gates of towns, and, in short, in all buildings where they wish to show magnificence.

"I have seen, in several quarters of Canton, four different kinds of *tings*. The three first are found in temples, and the fourth in many gardens.

"The most common form in these temples is seen in *Plate* I., (see Chambers' work.) It is a pretty exact copy of the *ting* of the Nagada of Cochin-china, in the eastern suburb. I have measured many buildings of this kind; but have found so much difference in their proportions, that I am inclined to think the architects, in that particular, follow no exact rule, but that every one varies the proportion according to his fancy.

"In the drawing that I have given, the edifice is, as they all are, raised on a base; the ascent to it is by three steps. It is a square, surrounded by a colonnade of twenty columns, which support a roof surmounted by a wooden balustrade, which contains a gallery, or passage, surrounding the whole second story.

"The second story has the same figure and the same dimensions as the first. It is covered with a roof, of a construction peculiar to the Chinese; the angles are enriched with ornaments of sculpture, representing dragons.

"The breadth of the edifice, measuring it from the exterior surface of the columns, is equal to the height; and the diameter of the body of the building takes two-thirds of the breadth. The height of the order makes two-thirds of the diameter of the body, and the height of the second story is equal to two-thirds of the height of the first. The columns have in height nine of their diameters, the bases two, and the beams and brackets, which hold the place of capitals, only one. That is also the elevation of the entrelases, which make the turn of the colonnade under the first roof, and which forms a kind of frieze.

"The second kind of *ting* differs so little from that which I have just described, that it has not appeared to me necessary to give a drawing of it. The first story is the same, and all the difference of the second, is, that it is neither surrounded with a gallery nor with a balustrade, and that the roof which covers the colonnade comes close to the wall.

"The third kind is represented, *Plate* I., *Figure* 3. This drawing has been taken from several edifices of this kind; and particularly from one of the pavilions of the pagoda of Honang. The first story differs little from that of the first *ting;* but the second has columns on two of its sides, which stand out and form covered galleries. I have seen, in some of these buildings, a continued colonnade all round the second story; but the form was not so agreeable to the sight as that which I have represented.

"There is very little difference between the proportions of this drawing and that of *Plate* I. The columns of the first story are, in height, eight of their diameters, and the bases one. All the columns, except those of the corners, have eight brackets at the top of their shafts, which form a kind of very clumsy capitals. This ornament, very common in Chinese edifices, is not at all pleasing to our eyes. The columns of the second orders are in diameter about four-fifths of the diameter of the first. Their height is six diameters and a half, and they are without bases. Under the second roof is seen an entrelas, all around, composed of circles and squares. The corners of the two roofs are enriched with ornaments, which represents monsters and foliage; and the top is ornamented with two dolphins at the two extremities, and in the middle with a great fleuron resembling a tulip.

"These three forms are more frequent than any other in the temples of China, and especially in those of much extent. For the small temples they often use the model shown in *Plate* I., *Figure* 2. Sometimes, as may be seen in that drawing, the edifice is shut before by movable gates, having four columns that advance in the manner of pro-style temples. At other times the building is quite open in the front, and has simply four columns that support the roof.

"I have seen at Canton some other forms of temples; but none of them appeared to me worthy of representation except two little buildings, of wood, raised in the courts of one of the pagodas of the western suburb. (*Figures* 2 and 3, of *Plate* III. he gives the plans of them.) These are two pavilions, that cover two iron vases, that the Chinese use in the sacrifices of gilt paper, which they make to their idols on festival days; they are both octagons, and composed of eight columns, which support a roof surmounted with a lamp and other ornaments, which are represented in the drawing. *Figure* 3, is a little raised, and surrounded with steps. The columns have bases of a profile little different from the attic. A frieze charged with inscriptions in large Chinese characters, surround the space between the columns under the roof. The lantern has eight sides, it is covered with a roof in sima inversa, and on the top is seen an ornament consisting of a small globe surrounded with leaves and flowers."

Figure 2, "is raised on a socle, and surrounded with an entrelas of masonry. There are no bases to the columns, and under the first roof is seen an ornament composed of interwoven lozenges. The lamp has eight little columns, without bases or capitals, which support a conic roof, ornamented with eight dolphins, each of which rests on one of the columns. The top of the building consists of a pierced ball, whose top ends in a flower.

"The proportions of these little temples may be deduced from the scale that I have annexed to the drawings."

"*Towers*, or *Taas.*—The Chinese give the name of *taa* to their towers, and the Europeans call them (as well as temples) *pagodas:* they are very common in China. Du

Halde says, that in some provinces they are in every city, and even in every considerable village. The most remarkable of these edifices are the famous porcelain tower of Nang-king and that of Tong-chang-fou. They are both very magnificent.

"The form of these *taas* is pretty uniform; they are octagons, divided into seven, eight, and sometimes ten stories, which diminish gradually both in height and breadth, from the base to the top. Every story has a kind of cornice, which supports a roof, at the corners of which are hung copper bells, and is surrounded with a narrow gallery bordered with a balustrade. These edifices have commonly a long pole at the top, surrounded by several circles of iron, supported by eight chains, tied by one end to the top of the pole, and by the other to the angles of the roof of the highest story."

The origin and objects of these towers have been the cause of much discussion among European antiquaries, nor has the question been as yet satisfactorily settled, some considering them as merely commemorative, some as campaniles or belfries, some as landmarks and beacons, while others assert that they are sepulchral, and produce as a confirmation of their opinion the discovery of a stone coffin fitted in the pedestal of the tower of Ardmore. Vallency affirms that they were fire-towers erected to Baal, while others no less learned identify them with the round towers of Ireland. This last idea may appear extravagant at first sight, yet upon further examination it will be found equally as reasonable as any of the preceding. The Irish towers are generally believed to be of Celtic origin, erected by the same hands as the structures of Stonehenge, and others similar to them scattered over the British Isles; now, strange to say, we have the same class of erections in China, in the province of Keang-nan, and in a locality famed not more for its romantic scenery than its ancient legends: here we find not only the monolithon, or single, upright column, the counterpart of those already described under *Celtic Architecture;* but even the most perfect form of Druidical structures, the circle, and several of the intermediate erections, proving without doubt the connection between them, and the remains of Celtic erection in the remote west. Add to this, that towers are found in close proximity with such structures, and it must be allowed that their supposed identity with those of Ireland is not indulged without some reason.

Plate III. *Figure* 1, "represents one of these towers, which are found on the banks of the Ta-ho, between Canton and Hoang-pou. It is approached by three steps, and consists of seven stories. The first story is pierced with four arched gates, and contains an octagonal chamber, in the middle of which is a staircase conducting to the second story. The stairs of the other stories are placed in a similar manner. The cornices over the several stories are all alike, consisting of a fillet and large cavetto, enriched with representations of shell-fish; an ornament as common in the edifices of China, as in those of the ancients. The roofs are turned up at the corners, and, with the exception of the lowest, are ornamented with leaves and bells. The pole on the top is surmounted with a globe, from which descend chains, that are fixed to the angles of the highest story, and around them are nine iron hoops. I have not set down the stairs of the different stories in the drawing, to prevent confusion."

The porcelain tower of Nan-king is octagonal in plan, forty feet in diameter, and consists of nine stories, diminishing in size as the structure rises, and surmounted with a cupola and gilded ball. From this ball a rod of iron rises, and from its highest extremity eight chains descend, from which seventy-two bells are suspended. Each story is covered by a projecting roof of coloured tiles, and the total height of the building is variously estimated at three hundred and forty-six, two hundred and fifty-eight, and two hundred and thirty-six feet.

"The inner part or body of the wall," says Mr. Wright, "is brick, but the inside lining and the facing without, of beautiful white glazed porcelain slabs, fixed in the masonry by means of deep keys, cut like a half T in the brick. The projecting roof of each story consists of green and yellow porcelain tiles in alternate perpendicular rows; and running up each angle, is a moulding of larger tiles glazed and coloured red and green alternately. From each story projects a balcony, enclosed by a light balustrade of green porcelain, upon which open four doorways, set to the cardinal points, their arches being elegantly turned with glazed tiles, cast in all imaginable fancies of design, and variation of colour, representing deities, demons, and monsters of all descriptions." Bells are suspended from dragons' mouths at the angles of every story, making with those attached to the chains of the cupola, a total number of one hundred and fifty-two.

"*Several other forms of buildings used in China.*—I have given descriptions of three kinds of *tings*, that I saw in different temples at Canton. It remains for me to speak of a fourth kind, which is found in gardens. These edifices are in general composed only of twelve columns, raised on a socle, which serve to support the roof.

"The building that served me for a model, was placed in the middle of a small lake, in a garden in China; its singularity made me give it the preference.

"The base that supports it is pretty high. A balustrade surrounds it. The bases of the twelve columns of this pavilion have a profile very similar to that of a Tuscan base of Palladio. The roof, which rests on these columns, is crowned with a lantern. The idea of this ornament is taken from those which surmount the towers. The tops of the shafts of the columns are pierced by beams that support the roof, having their extremities ornamented with little grotesque heads and bells. A frieze ornamented with an entrelas, goes all round, under the roof, in the spaces between the columns."

Sir William describes another pavilion thus: "It is the same with that of a temple with one wing; but the elevation is different. It is composed of ten columns, which support a roof and a lantern, covered in the form of a cone, and terminated by a ball.

"The *paylous*, or triumphal arches, are very common in China. There are many in Canton; but none, that I have seen, have any beauty.

"*Houses of the Chinese.*—The distribution of their houses is perfectly uniform; and it would be improper, and even dangerous, for an individual to depart from the general mode. Le Compte tells us of a mandarin, who having built a house higher and more beautiful than those of his neighbours, was accused before the Emperor, and, fearing the consequence, he pulled down his house, without waiting for the sovereign's decision.

"The Chinese lay out more than half of the ground occupied for their houses in courts and narrow walks; those of the merchants of Canton, which are close by the water, are narrow and very long; but there is no difference in the disposition of their interior. The level ground is crossed in its length, by a broad walk, passing through the middle, and stretching from the street to the river. On each side are the apartments, consisting of a saloon for receiving visits, a bed-chamber, and sometimes a study, or closet. Before each set of apartments is a court, having a fish-pond, or cistern, at its extremity, containing an artificial rock in the middle, whereon grow bamboos and several other kinds of

plants; all which form a miniature landscape, of picturesque appearance. Some of the fish are so familiar, that they come to the surface of the water, and allow themselves to be fed with the hand. The sides of the courts are ornamented sometimes with flower-pots, and sometimes with shrubs in flower, vines, or bamboos, forming green arbours. In the middle, upon a pedestal, a large porcelain vase is generally placed, filled with those beautiful flowers, called *lien-hoa*. They also frequently keep in these little courts, pheasants, bantam-hens, and other curious birds.

"The great chamber, or saloon, is commonly from 18 to 20 feet in length, and about 20 feet in breadth. The side which looks to the court, is entirely open; but a screen of canes, which is let down at pleasure, keeps out the rain and the rays of the sun. The pavement is composed of pieces of stone or marble, of several colours. The side walls are covered with screens, to the height of three or four feet from the ground; and the upper part is neatly decorated with white, crimson, or gilt paper.

"Instead of paintings, the Chinese hang up large pieces of satin or of paper, set in frames, and painted in imitation of marble or bamboo, on which are written, in characters of azure blue, proverbs and distichs of morality, taken from the principal Chinese philosophers. They also sometimes have leaves of white paper, quite smooth, containing large characters, traced by some skilful hand, in China ink; this ornament is much esteemed. The bottom of the drawing-room is composed of folding-doors, over which is a lattice, covered with painted gauze, for the admission of light into the bed-chamber. The doors, which are of wood, are of very neat workmanship, ornamented with different characters and figures, and sometimes richly varnished and painted red, blue, yellow, or some other colour.

"In the middle of the lower part of the chamber, and above a table which contains various ornaments, a very large leaf of thick paper is frequently suspended, covered with ancient Chinese paintings of different figures, enclosed in squares. The Chinese have a great veneration for these ornaments, under the idea that the painters were inspired; and the connoisseurs pretend to distinguish the hands of the several masters, and give a very great price for such as pass for originals. I have seen many of these paintings: they usually consist of landscapes or figures, drawn with China ink, on white paper. In general they are touched with spirit, but they are too incorrect, and too little finished, to deserve much attention.

"The furniture of the large room consists of chairs, stools, and tables, made of rosewood, ebony, varnished wood, and sometimes simply of bamboo, which, though cheap, is very neat. When the furniture is of wood, the tops of the stools are often of marble or of porcelain; and though such seats are very hard, they are very agreeable in a climate where the heat of the summer is excessive. On small tables, or stands, four or five feet high, placed in a corner of the room, are seen dishes of citrons, and other odoriferous fruits, branches of coral in porcelain vases, and glass globes containing gold-fishes, with a kind of herb something similar to fennel. They also decorate their tables, which are made only for ornament, with small landscapes, composed of shell-work, plants, and a kind of lily that grows among pebbles covered with water. They have also artificial landscapes, made of ivory, crystal, amber, pearl, and precious stones. I have seen some that cost a thousand *taels*, (more than three hundred guineas), but they are mere toys, and wretched imitations of nature. Besides these landscapes, the tables are ornamented with porcelain vases of different kinds, and small copper vessels, the latter of which are much esteemed. The forms of these vessels are generally simple and agreeable; the Chinese say they were made two thousand years ago, by some of their most celebrated artists; and such as are really antique, (for there are some counterfeits), sell at an excessive price; one of them sometimes costs no less than three hundred pounds. They are kept in small pasteboard boxes, and are only shown on great occasions; nobody touches them but the master, and, to keep them clean, he brushes them from time to time with a hair-pencil, made solely for the purpose.

"Lamps form the most prominent ornaments of the chambers; there are generally four of them hanging from the ceiling, by cords of silk. They are of various shapes, as square, octagon, &c., and are composed of an extremely fine silken stuff; decorated with very neat drawings of flowers, birds, and landscapes.

"A partition of folding-doors separates the large room from the bed-chamber. I have already observed, that, in warm weather, these doors are left open all night, for the admission of cool air. The chamber is very small, and has no other furniture than the bed and some varnished clothes-trunks. The beds are sometimes extremely magnificent: the bedsteads, or frames, which very much resemble those of Europe, are of rosewood engraved, or of lackered wood; the curtains are of taffety, or gauze, sometimes flowered with gold, and commonly dyed blue or purple. A band of embroidered satin, about a foot in breadth, goes round the whole top of the bed; the embroidery is in compartments, of various forms, and represents flowers, landscapes, or human figures, accompanied with moral sentences and fables, written with China ink and vermilion.

"By the side of the bed-chamber is a passage, leading to the cabinet, which is always enclosed by walls, and lighted by windows. The walls are ornamented, like those of the saloon, with moral sentences and antique pictures; the furniture consists of arm-chairs, settees, and tables. The books are disposed on shelves, and on a table near the window, lie the pencils, and other things necessary for writing, the instruments used for arithmetical calculations, and some select books, all laid out in great order.

"Besides these apartments, there are also the dining-room, the kitchen, the apartment for the domestics, the bath, the privy, the office, or counting-house, and, towards the street, the shop.

"Such is the distribution of the houses of all the merchants at Canton. Those of other people only differ in having their general plan accommodated to the ground on which they are built: for the apartments, the courts, and other conveniences, have everywhere the order just described.

"The *leou*, or upper-story, consists of many great halls, occupying all the breadth of the house, above the apartments of the ground-floor. They are used occasionally as chambers, for lodging strangers. In every house there is a number of shutters, two or three feet broad, and ten or twelve feet high. When they wish to make chambers, they fix these shutters to the floor and ceiling, and in a few hours make as many apartments as they wish. Some of these shutters are cut from the top to within four feet of the ground, and the openings filled with very thin oyster-shells, which are sufficiently transparent to admit daylight. All the windows in China are made of these shells.

"In one of these great halls, and commonly in that next the door, the image and altar of the domestic idol are placed, so that all who enter may see it. The rest of the second story is divided into apartments for the family; and over the shops are the rooms for the shop-keepers.

"The sides of the Chinese houses next the street, are altogether plain, or employed as shops. There is no opening

except the door, before which a mat is hung, or a screen is placed to prevent passengers from looking in. The houses of the merchants of Canton have a very gay and handsome appearance towards the river.

"The materials used for building are wood and brick. The latter are either simply dried in the sun, or baked in an oven. The walls of the houses are commonly about eighteen inches thick, and the bricks, which are about the size of our own, are used in the following manner: the masons place three or four beds at the foundation, entirely solid; after which they dispose their bricks alternately length and breadthwise, along the two sides of the wall, so that those laid across touch one another, and occupy the whole breadth, but those placed lengthwise have a space between them; on this layer, or bed, a second is laid, with all the bricks lengthwise, and the joinings of the cross-bricks, in the first layer, are covered with a whole brick in this. The work is thus continued, alternately, to the top; and by this means, the expense of work and time, as well as the weight of the wall, are very much diminished.

"The tiles that cover the roofs, are plain and semi-cylindrical; the latter are laid on the joinings of the former, and the manner in which they are supported, is represented in Plate III. The Chinese, like the Goths, always let the wood appear withinside the ceiling; for which reason, the beams and columns are frequently made of precious wood, and sometimes they are richly inlaid with ivory, copper, and mother-of-pearl.

"*Various kinds of columns used by the Chinese.*—Columns are at least as common in Chinese edifices as in those of the Europeans. They support the roof, and are commonly made of wood, with bases of stone, or marble, having no capitals; but, instead, the top of the shaft is crossed by the beams. Their height is from 8 to 12 diameters, diminishing gradually towards the top, while the lower part of the shaft terminates in an ovolo, producing an effect just the reverse of the terminations of the ancient columns. This peculiarity is observable in the drawings of the *Antiquities of Egypt*, published by Captain Norden some time ago. The bases show a great diversity of profile; none of them are very handsome, but the most regular that I have seen, are the six represented in Plate III." *See Chambers*' Work.

Figure 2, No. 1, "is taken from the colonnade that surrounds the court of the pagoda of Cochinchina: the column is about seven diameters in height, and the base one. This profile is very common."

Figure 2, No. 2, "is taken from one of the temples of the same pagoda, represented in Plate I. It is the only place where I have seen this kind of column. They are about nine diameters high, and their base two."

Figure 3, "is taken from the colonnade of the great court of the pagoda of Honang. The height of the column is nine diameters, and that of the base one. The ends of the beams are ornamented with heads of monsters, terminating in foliage, and the brackets that support them come out of the mouths of grotesque heads, cut in half-relief on the columns."

Figure 4, "is taken from a little pagoda in the eastern suburb of Canton. The height of the column is eight diameters and a half, and that of the base three-fourths of the diameter. The ends of the beams represent heads of dragons, and all the wood-work of the ceiling is ornamented with monsters and foliage, in inlaid work of copper, ebony, ivory, and mother-of-pearl."

Figures 5 and 6, "the transverse elevation of Figures 3 and 4."

Figure 7, "is seen in almost all the houses of the Chinese. Their height is from 8 to 12 diameters, and sometimes more; that of the base is from one-half to two-thirds of the diameter. The profile resembles one of the Tuscan bases of Palladio."

Figure 8, "is found in almost all the pagodas, with some little varieties. The model from which I have taken my drawing, is in a little pagoda, in the street where are the European factories. The columns are octagonal, and of stone. Eight diameters of the circumscribed circle make the height; and they have no diminution toward the base. The bases are the most regular that I have seen in China, and much resemble the attic base of the ancients. Their height is equal to double one of the sides of the column.

"The particular divisions of all these profiles are marked at the side of each drawing.

"The insides of the temples, represented in Plates I. and II. (see *Chambers*), are quite plain; having no ornaments beside the idols. The buildings represented in Plate II. Figures 3 and 4, have no ceilings; the beams which support the roofs are seen; and their joinings are according to the principles of that in Plate III. The interior of the tower in Plate III. is also quite plain."

We must not omit to mention the Great Wall; it consists of an earthen mound supported on each side by walls of brick and masonry, the thickness of the whole being twenty-five feet at the base, diminishing to fifteen at a height of fifteen feet, which is the level of the platform; but this platform is defended on either side by a parapet five feet in height, thus making the total height of the wall twenty feet. At intervals of about two hundred paces are towers, rising to a height of thirty-seven feet, and measuring forty feet square at the base, and thirty feet at the top; there are however some larger towers, which consist of two stories, and are about forty-eight feet in height. This wall is carried round a great portion of the empire, passing over in its way mountains, valleys, and rivers, and is altogether fifteen hundred miles in length.

CHIP, a small piece cut away from any material, by an acute-angled instrument.

CHISEL, an instrument used in masonry, carpentry, and joinery, and also by statuaries and carvers, for cutting, either by the impulse of pressure, or of the blows of a mallet or hammer. There are several kinds of chisels used in carpentry and joinery; as, the *former*, the *paring-chisel*, the *gouge*, the *mortise-chisel*, the *socket-chisel*, and the *ripping-chisel*. These names they have obtained from the uses to which they are respectively applied. *See* TOOLS, TOOLING.

CHISELED WORK, in masonry, stones that have a chiseled surface.

CHIT, an instrument for cleaving laths.

CHOIR, (from χορος, Greek, chorus;) that part of the church in which the choir or singers are located, and the services for the most part performed. The term is sometimes made equivalent to chancel, and defined as that portion of the building eastward of the nave appropriated to the priests, but incorrectly so, as the choir does not extend to the extreme east. The fourth council of Toledo directs "the priests and deacons to communicate before the altar, the inferior in the quire, and the people without the quire;" thus making a distinction between the choir and sanctuary, or division on which the altar stood. In fact the chancel is divided into two parts—the choir, and the presbytery or sanctuary; the former containing the singers and inferior ministers; the latter the altar, and the superior officiating clergy. The choir was at the western end of the chancel, separated from the nave by one or more steps and the rood screen, and from the sanctuary by steps only; it contained seats or stalls on either side, which were returned sometimes on the western extremity in front of the screen, the returns always

facing the altar: in large churches, there are generally two or three ranges of such stalls rising a step or two in succession above each other. When there are aisles at the sides of the choir, which is generally the case in cathedrals and the more important churches, they are separated from it either by a screen of open work, or by the stalls being carried up to a considerable elevation; the latter method is more usual in cathedrals, where the higher stalls are canopied, and enriched with tabernacle work. In our cathedrals, the choir is situate more generally to the east of the tower, but is sometimes seen under the tower, as at York and Winchester.

The choir was originally separated from the altar, and elevated in the form of a theatre, enclosed all round with a balustrade: on each side was a pulpit, from which the epistles and gospel were sung; as may still be seen, at Rome, in the churches of St. Clement and St. Pancratius, the only two remaining in the original form. It was separated from the nave in the time of Constantine, and enclosed with a balustrade, covered with curtains, which were not to be opened till after the consecration. In the twelfth century, the choir was surrounded with walls.

In nunneries, the choir is a large hall, adjoining the body of the church, but separated by a grate, where the devotees chant the service.

CHORAGIC MONUMENT of Lysicrates, at Athens. *See* MONUMENT OF LYSICRATES.

CHORD, the extent between the two extremities of an arch.

CHRISTIAN ARCHITECTURE, a designation applied by some to Gothic art exclusively, but in our opinion, unreasonably; because, although Gothic is doubtless the perfection of Christian art, and the best adapted for religious purposes, and in that respect more fairly entitled to the name than any other style, still we think all others ought not to be excluded from the title, since some of them, such as Byzantine and Lombardic, owe their origin entirely to Christianity, and were never profaned by being applied to pagan usages. The term ought to include all styles of building invented by the Christians, and adapted to religious purposes, differing essentially from pagan architecture.

CHRONOLOGICAL COLUMN. *See* COLUMN.

CHURCH, (Greek, Κυριου οικος, the Lord's house,) a Christian edifice set apart for the public celebration of divine service.

Churches vary in size, magnificence, and architectural features, according to their rank and situation; and are denominated accordingly: thus we have metropolitan, patriarchal, cathedral, cardinal, conventual, collegiate, monastic, and parish churches; for a description of which, we must refer to each separate title, more especially to CATHEDRAL and MONASTERY. Under this article we shall confine ourselves more particularly to the consideration of parish churches; as, however, the distribution and architectural peculiarities of churches vary considerably in different countries, we must premise further, that we include only the parish churches of our own country. The history and progress of Church Architecture in this and other countries, and a comparison of the whole, will be treated of under the title of ECCLESIASTICAL ARCHITECTURE.

As there is a general similarity in the division and arrangement of parts in all churches of whatever date or situation, it may not be out of place at the commencement of this article, to say something of the primitive churches, as far as relates to these particulars. The earliest buildings erected for the purpose of Christian worship, or at least the earliest of which we have any account, as also the first in which Christians had an opportunity of following their own mode of construction, are those which owe their existence to the zeal of Constantine the Great; and the most ancient and most perfect model of these now remaining, is that of Saint Clement at Rome. From this and some few other structures at Rome, we are enabled to determine, to a certain extent, the form of the churches of that period; and our conclusions derived from this source, are confirmed by Eusebius, who has left us a description of a Greek church of his own time. From these combined authorities, we learn that the plans of such buildings were either oblong or cruciform, and were divided into distinct portions as follows:—At the entrance to the church was the vestibule or narthex, in which were stationed the catechumens and penitents of various stages, and which was frequently divided into two or more parts, each of which was destined for a different class of penitents, the outermost for those who were under the more severe censures of the church, and the innermost for the catechumens; this last division was termed ναρθηξ, *ferula*, because those who were admitted into it, began to be subject to the discipline of the church. These vestibules or porticos led to the nave properly so called, in which were assembled the body of the faithful; and which was divided in its width into three or more parts—a central one, with an aisle on each side of it. In the central avenue or body of the building, and at the remote end of the nave, was the choir, shut off from the other parts of the church by a rail or otherwise; in this were the ambones or pulpits for reading, as also the seats for the choristers, and here was the greater portion of the service performed. From the choir was an ascent of steps to the sanctuary, which was of an apsidal form, having seats all round for the priests, and a more elevated one in the centre of them for the bishop, immediately in front of which stood the altar. Attached to the church, but forming a distinct erection, was the baptistery, in which persons were admitted into fellowship with the body of believers. Having thus given a rapid sketch of a primitive church, we shall pass to the consideration of our more immediate subject, begging our readers to bear in mind the preceding observations, while we describe the form and arrangement of our English churches.

In speaking of our parochial churches, we would be understood to refer solely to those erected before the Reformation, in the styles usually denominated Gothic. This is not the place, even were argument necessary, to discuss the comparative merits of the Italian and Gothic styles, or their adaptation to sacred purposes. The improved taste of the age has led to the preference of the latter, and there are few of the present day who would be found to question its correctness. Gothic is the prevailing fashion now, as was Italian in the preceding generations; apart from this, however, we think there can be no man of correct taste and unbiassed judgment, but would prefer the quiet unobtrusive simplicity of our old parish churches, to the more pompous grandeur of those of the last two centuries. Nothing can be more diverse than the impressions conveyed by the two—the one, solemn, subdued, and peaceful; the other, secular, showy, and luxurious: it is astonishing how completely the application of the two styles to the same general form, will change the features and general appearance of an edifice.

Our parish churches are perfectly unique; different from what we find elsewhere, they form quite a national characteristic, of which an Englishman may indeed be proud. Their origin is attributed to Archbishop Theodore, who noting the inconvenience which arose from the previous practice of sending priests from the cathedral into the neighbouring hamlets, adopted the plan of distributing each diocese into manageable districts or parishes, with a resident pastor to take charge of each; he carried out his idea by instigating

the Saxon thanes in the erection and endowment of churches within the precincts of their own estates. The plan thus commenced, was found to be so advantageous, that it was carried out and enlarged upon by the succeeding generations. We shall not stop here to inquire into the form and construction of the earlier churches of this island, but refer the reader, as well to the articles above mentioned, as also to that on SAXON ARCHITECTURE, and proceed at once to the general description of a church.

Of the parts or divisions.—There are two parts, and only two parts, absolutely essential to a church: nave and chancel. These it must have, or it is not entitled to the designation of a church; without the former it is no more than a chapel, and without the latter, little better than a mere lecture-room. A church consisting only of the above divisions, is one of the most simple form, few, however, are found without some further additions: the first addition is that of a porch on one side of the building, forming a covered entrance into the church. Buildings consisting simply of these three parts are not unfrequent, nor devoid of beauty, although but seldom imitated in the present day. In larger churches, the capacity of the nave is increased by the addition of one or two aisles, more frequently of one on each side of the body of the building, thus dividing the nave transversely into three avenues and affording greater accommodation for worshippers without enlarging the chancel, as this part does not so much require spaciousness as length. In some cases it is true the aisles were continued eastward, so as to encroach upon the chancel, and sometimes extended its whole length; the spaces thus gained, were used for the most part for chapels, and contained side-altars with their appurtenances. These chapels were dedicated, the one in honour of the Virgin, which was more frequently on the southern side, and the other in the name of the patron or other saint. Churches with only one aisle, are constantly to be met with.

Another division of a church which we have not yet noticed, and which, though not an essential, forms a most imposing feature, is the tower; this is situated most usually at the western end of the nave, or at the intersection of the nave and transepts, when the church is cruciform; and in its most perfect and beautiful state is surmounted by a lofty spire. We have now arrived at the most complete form of a parish church, which consists of a nave flanked on either side by an aisle; a chancel at the east, and a tower at the western extremity of the same, with a projecting porch towards the western end of the south aisle. This is the most frequent form of our smaller churches, but not the only one; we not unfrequently find them in the shape of a cross, which is doubtless the most appropriate and expressive form that could be adopted in the erection of a Christian temple; but the simple parallelogram is on many accounts the more convenient, nor is it so greatly inferior in symbolical meaning; for while the cross plan portrays the emblem of Christianity, the latter is an evident representation of the ark in which Noah was preserved, which has ever been considered a type of the Christian church.

Of the position of Churches.—Almost all the old churches of this country range east and west, having the chancel at the eastern extremity; nor is this merely a local peculiarity, but a universal custom; such was the practice of all Christians from the earliest ages. It is true, exceptions are to be found, but not more than sufficient to prove the rule. The church dedicated by Paulinus, bishop of Nola, to the memory of S. Felix, is an instance of deviation from the usual position, but of this it is related, that it was not built so as to face the east, "as was usual," but so as to turn towards another church previously dedicated to that saint; and Socrates, describing the church at Antioch, tells us, that it stood in a different posture from other churches, the altar not being at the east end, but at the west. The canonical position is ordered in the apostolical constitutions. When we state that the chancel pointed eastward, we do not mean to say that it faced that quarter precisely; very few churches indeed do this, the orientation varying in many instances considerably north or south; such variation is said to have arisen from the practice of pointing the church to that part of the horizon where the sun rose on the day of the patron saint.

Of the exterior elevation.—The smaller churches present to us an elevation of only one story of rough walling, pierced at intervals with windows, which are usually filled with tracery; those at the east and west ends, being of larger dimensions than those in the side walls. At the angles of the building, the outline is broken by massive projecting buttresses, and at other situations where they are required for the support of the building; they are sometimes seen between every two windows. A more imposing projection is afforded by the porch on one side; this is carried up nearly as high as the side walls, and is surmounted by a high-pitched gable roof; it is formed either of rubble, with or without windows, or of wood, in which material we have many beautiful specimens of the later styles pierced and carved in the most elaborate manner; some of the plainer ones, however, form very picturesque additions to a small church.

The chancel, in most cases, is of smaller dimensions than the nave, both in width and height, and forms a picturesque break in the elevation; but in some cases it is of the same size as the nave, and occasionally, though rarely, larger in both dimensions, showing a western wall projecting beyond the nave on all its sides. There is a priest's door in one side of the chancel, and sometimes a vestry, the form and elevation of which varies in different examples.

The whole of the building is covered by a high-pitched gable roof of lead, slate, or tile, and sometimes of shingles or thatch, the eaves projecting a little beyond the walls; parapets are not found, except in large churches. A very beautiful addition is frequently to be seen on the apex of the western gable, consisting either of a continuation of a part of the gable in a vertical direction, pierced with arched apertures to contain the bells, and finished with a gable top; or otherwise of a little turret of four or more sides, to be employed for the same purpose: the eastern gable is for the most part finished with an ornamental cross.

In the larger churches of three aisles, the elevation consists most frequently of two stories, the lower one similar to that already described, and an upper one called the clere-story, which is carried up above the arches which separate the nave and aisles, and pierced with windows of a smaller description, sometimes with mere quatrefoils or other small apertures. In very large churches, the clere-story windows are often larger than those of the aisles. The nave is covered as before with a gable roof, but the aisles with a lean-to, sloping upwards from the exterior walls to the clere-story, with a much more gentle acclivity. In some three-aisled churches, where the width is not considerable, the gable roof spans both nave and aisles; sometimes in one inclination, but at others, the inclination over the aisles is considerably depressed; in such cases there is of course no clere-story. On the other hand, when a church is of a great width, especially when the additional width is in the aisles, we have three gable roofs, one over the nave, and a similar one over each aisle; the gable ends of such churches have a very pleasing appearance; they have no clere-story, and the chancel is mostly but a continuation of the nave; not unfrequently the aisles are continued the whole length of the building in such churches.

In cruciform churches, the elevation, with the exception of such differences as the plan necessitates, is for the most part similar to that of the more common forms.

Of the tower.—A beautiful appendage to a church is the tower, nor is it added merely for effect; its principal object is perhaps to contain the bells, which require to be suspended at a considerable height, in order that they may be heard at a distance; another end which it serves, is to point out the situation of the sacred building, and, as some suppose, to act as a beacon or landmark for the guidance of travellers: an instance of a tower serving this purpose, may be pointed out at Boston, Lincolnshire, as also at Dundry, near Bristol, at both of which places the towers are raised to an extraordinary height. The tower is very generally surmounted by a spire, which serves as a most efficient covering, while at the same time it gives additional height, and forms a beautiful finishing, "pointing," as it does, "in silence heavenward." It is remarked that spires are not so frequent in elevated situations, or in level tracts of land, as they are in valleys and in wooded country; which fact would seem to imply that they were added more especially for pointing out the spot occupied by the house of prayer.

The situation of the tower with respect to the church is various; sometimes we see it at the end, sometimes in the middle of an aisle, frequently at the west end of the nave, and occasionally between nave and chancel; in short, almost in every situation, except at the eastern extremity of the chancel. Its plan is usually square, though occasionally we find it octagonal, and even circular, and sometimes square at the lower part, but finished off at the top in an octagonal form; in elevation, the outline is broken by buttresses projecting considerably at each angle, and, where there is no spire, is frequently found a stair turret running up in the corner next the church, and continued some little distance above the parapet. The base or lower story of the tower is usually plain and massive, but the upper portion is of a more elaborate appearance, being pierced with windows, the heads filled with tracery, and the lower parts with louvre-boarding. When there is no spire, the tower is finished with a parapet, battlemented or otherwise; and in later examples, the parapet is not omitted, even when there is a spire, and is sometimes enriched by continuing the buttresses above the tower, in the shape of pinnacles. During the earlier periods of English architecture, the spires sprang direct from the eaves of the tower, without the intervention of a parapet.

Spires are, in plan, square or multangular, most frequently octagonal; sometimes they spring from the tower on a square plan, which at a short elevation is merged in the octagonal; some spring from the tower at a greater angle than others, but all terminate in a point surmounted by a vane, often by the symbolical cock, the emblem of St. Peter's fall, which proposes an opportune warning to the passers-by, not to neglect the aid of divine power, but to "watch and pray, lest they likewise enter into temptation." The elevation of the spire is relieved by one or two tiers of spire-lights, which are small open windows, carried up vertically, and therefore projecting from the line of spire as they rise upwards. Spires are built either of stone or of wood, in which latter case, they are usually covered either with lead, slate, or shingles; and though not so imposing as those of stone, have a very picturesque appearance. Towers of wood are very frequent in Sussex, Surrey, and Essex; they are surmounted with low spires, the whole being covered with weather-boarding, with small apertures of luffer-boarding for windows: wooden bell-cots of a similar description are commonly to be met with in Essex. Detached towers are not of frequent occurrence in this country, but several are to be found, especially in Lincolnshire.

Of the internal structure.—The principal portion of the structure to which the eye is directed, in the interior is the chancel; this is entered from the nave under an arch, termed the chancel-arch, and is elevated from the body of the church on a raised platform, which is ascended by three or more steps; a further separation is effected by the rood screen, which is carried across the opening formed by the arch, and stretches from pier to pier. In three-aisled structures, the aisles are separated from the nave by an arcade or series of arches, supporting in most cases a clere-story, to admit light into the body of the church. The proportion between the width of the nave and aisles, varies considerably; in some cases, the aisles being less than half the width of the nave, and in others, of nearly equal dimensions.

The roofing throughout the church is composed in by far the majority of instances, of timber, the few exceptions, which are in the larger churches, being of stone vaulting. In roofs of the former kind, the timbers were originally open to view, and not concealed, as too many of them are at the present day, with a flat plaster-ceiling. The timbers were of oak, and consisted of principals, purlins, and common rafters, the whole of which were boarded over, and the boards protected by lead or other covering. The principals are placed at regular intervals, dividing the roof into a number of bays or compartments, each inclosing several common rafters, and are partially supported either on corbels, or on the capitals of shafts ascending from the floor; they are formed either of collars with collar braces continued to the lower part of the rafter, of collars with intersecting collar braces, of intersecting braces only, or of timbers disposed in the form of an arch, and in many other ways which will be discussed in the proper place; tie beams are seldom used; in most instances the timbers are plain, but in many, of the later ones more especially, a considerable degree of ornamentation is introduced in the shape of carved bosses, open panelling, and such like.

Of the internal arrangement.—On entering the church through the wicket, at the entrance of the porch, we sometimes notice on the right-hand side of the door, often projecting from the wall, and partially covered by a niche, a stone bason, which is called a stoup, or aspersorium, from its use, which was to contain the holy water, with which, in olden times, the worshippers sprinkled or crossed themselves before entering into the body of the church. This was a very ancient practice, and was adopted in a somewhat different shape by the early church; the small stoup, in fact, is a substitute for the fountain to be seen in front of some of the Constantinian churches, at which Christians were accustomed to wash before entering the sanctuary; the custom is typical of the purity of mind which should accompany our devotions. Before proceeding further, we may notice the stone seat, or bench-table, which runs along the sides of the porch, and is occasionally covered with an arcade, and sometimes surmounted with a window to give light to the porch: in ancient times, several religious ceremonies took place in the porch, especially those preliminary to baptism and matrimony. Having passed under the inner arch of the porch, we are now fairly in the church, and the first object to attract our attention is the font, which is placed always near the principal entrance, as being the most fitting situation for the performance of that rite by which men are admitted into the membership of the church; the exact locality is not fixed, being sometimes in the central avenue of the nave opposite the entrance, and at others under one of the arches of the aisle near the porch, in which case it frequently adjoins one of the adjacent pillars; it is not unfrequently raised on a series of steps, which give it a more imposing appearance,

and has always a space left around it for the accommodation of the priest, sponsors, &c.; for the former there is sometimes a kneeling-stone on the west side. Fonts in a perfect state are provided with covers, generally of wood, some flat, and others of a pyramidal form more or less enriched. We here speak of fonts as they were in former times, not as they are now found in old churches, for the original ones are sometimes not only moved from their ancient positions, but even taken out of the church, and altogether discarded.

On proceeding further into the church, the next object which probably strikes our eye is the chancel, and at its extremity the altar, with its appendages, but as this has been described in its proper place, we shall not stop to re-consider it here; and besides this, in fixing our attention on the more striking portion of the edifice, we have overlooked the pulpit. Few pulpits are to be met with of an earlier date than the fifteenth century, the oldest which remain are of stone, built up with the fabric, from which circumstance we may infer that they are coeval with the entire structure; there is a beautiful specimen at Beaulieu, Hants, which is attached to the wall, and entered by a staircase partly cut out of its thickness; another specimen is to be found in the church of the Holy Trinity, Coventry, which is attached to one of the piers of the building. The later pulpits are of oak, usually of an octagonal form, having the sides panelled and enriched with carving, and the whole sometimes surmounted with a richly-groined canopy projecting over the head of the preacher. The position of the pulpit was probably always at the north-east or south-east end of the nave, near the arch which separates the nave and chancel.

We have now to consider the form and arrangement of the pews. There are few churches which have not suffered severely by the removal of their ancient seats, and the substitution of close boxes, with high backs; the old seats were low, with very low backs, so as not to destroy or shut out a full view of the church. The backs and seats of such low benches were fitted at either end into a standard, which served at the same time as a support and finish, being frequently carved in panels, and sometimes finished at the top with a poppy-head, or knop of foliage; at other times they were quite plain, with only a simple moulding, or even chamfer at the top: between every two benches was an open space left for ingress and egress to and from the seats, which were never closed with doors. These benches were all arranged north and south, so that the congregation might face the east, having an avenue between them in the centre of the nave, and another leading into it from the entrance, which, in three-aisled churches, must have been carried right across the church, to give access to another avenue leading to the seats in either aisle. These formed the only seats in the church for the laity; it is scarcely necessary to add, that galleries never formed a part of the original arrangement.

Of the internal decoration.—There is one method of decoration so universally applied in our ancient churches, that we cannot pass it over unnoticed; it consists in the application of colour; the roof, the floor, the walls, the furniture and ornaments, and, not to omit the principal feature, the windows, nay, even the very books, were all enriched with gilding and colour. In paving, the use of encaustic tiles of various colours and patterns was most common, but besides these, the floors were not unfrequently covered with mosaic work, as instanced at the Prior's Chapel, Ely, where in the chancel immediately in front of the altar was represented "the temptation" in this method, the other parts of the floor being adorned with ordinary patterns. Frequent specimens of painting on the roof have been lately brought to light, a very usual method of decorating which is by a powdering of gilt stars on an azure ground. Few restorations take place without some additional testimony to the employment of fresco paintings, which have been previously concealed by successive coatings of plaster and whitewash. Mr. Poole, speaking of the internal decoration of churches, says—"Besides the immense variety of Scriptural and other subjects which are found sculptured on the walls and roofs of our Gothic churches, we have also sometimes fresco paintings, covering great portions of the walls. These paintings have, for the most part, been covered with the successive coats of whitewash and yellow ochre, with which the churchwardens have literally daubed the interior as well as the exterior of churches; as if, to their eyes, whiteness and yellowness were the only two elements of beauty. Accident has discovered several of them, and more are being discovered every day. The most remarkable with which I am acquainted is in the church of the Holy Trinity, Coventry; the subject is one which cannot be unprofitably suggested to Christians,—the last judgment; and it is treated in a manner by no means deficient in expression. At Preston, in Sussex, is another fresco, discovered also accidentally; one of the subjects is the murder of Thomas à Becket; the story is minutely and well told. Another subject is the archangel Michael weighing the soul of a Christian, which appears in one side of a pair of scales, against the devil, in the form of a boar's head, in the opposite scale. By the intervention of a female saint, most probably the blessed Virgin, who stands by, the soul is manifestly the weightier.

"In the late remains of Rotheram church, several frescos were discovered, especially a large one over the nave arch, of our blessed Lord and the twelve apostles, with other saints and angels in act of adoration. The figures were much destroyed in the process of laying them bare; and they are now covered over again. Might they not have been restored?" This question we shall leave for future consideration; meanwhile, we may remark, that many specimens of fresco have been discovered since the above was written, and no doubt fresh discoveries will be made as the process of restoration goes on in our ancient churches.

Another old method of decorating the walls, the appropriateness of which cannot be questioned, is by covering them with texts of Scripture, on which our previous author, Mr. Poole, remarks as follows:—"The most simple occupant of the walls of churches is a series of passages from the Sacred Scriptures, or of moral sentences of tried wisdom and appropriate tendency. The introduction of the inscriptions is very ancient. Bingham gives us several instances, and, among others, two distichs written over the doors of the church, one on the outside, exhorting men to enter the church with a pure and peaceable heart:—

> 'Pax tibi sit quicunque Dei penetralia Christi
> Pectore pacifico candidus ingrederis;'

and the other within, requiring those who go out of the church to leave at least their heart behind them:—

> 'Quisquis ab æde Dei perfectis ordine votis
> Egrederis, remea corpore, corde mane.'

"St. Ambrose tells us of an appropriate passage of Scripture, written on the walls of that part of the church which was allotted to the virgins. And besides these moral lessons and texts of Scripture, records of the dedication of the church were sometimes inscribed on the walls; such was that written by the altar of Sancta Sophia, by Justinian.

"To convey some notion how appropriately such passages may be selected and arranged, and how impressive may be their general effect, we will adduce the whole series of inscriptions from a small chapel at Luton, in Bedfordshire. This chapel, which is now the property of the Marquis of Bute, was built by one of the Napier family, in the reign

of James I., and the beautiful wainscoting with which it is fitted up, was brought from Tittenhanger, where it had been fixed by Sir Thomas Pope, in 1548.

"Over the principal doorway are the words, Domus Dei porta Cœli: 'The House of God is the Gate of Heaven;' and on the north and south side of the entrance: Laudate eum juvenes, laudate eum virgines, 'Praise Him, ye young men; praise Him, ye maidens,' from Psalm cxlviii. 12. On the two transverses of a beautifully carved door, is an inscription from Psalm cxviii. 20, Porta Domini, Justi intrabunt, 'This is the gate of the Lord, the just shall enter in.' With reference to a nearer approach to the altar, we have the words—Lavabo inter innocentes manus meas, et circumdabo altare tuum Domine: 'I will wash my hands among the innocent, and I will compass thine altar, O Lord:' and on the altar itself not only are the names of our blessed Lord, found in Hebrew, Greek, and Latin, as they were inscribed by Pilate on his cross, but also the following passages from Heb. xiii. 10; Matt. xxvi. 27; 1 Peter i. 12; and 1 Cor. xi. 24, 25: Habemus altare—Ex hoc omnes—in quæ desiderant Angeli prospicere—Hoc in memoriam mei: 'We have an altar—Eat ye all of this—Into which the angels desire to look—Do this in remembrance of me.' Even the singular addition of a chimney-piece in this chapel, has its appropriate inscription: Ecce ignis et lignum, ubi est victima holocausti? 'Behold the fire and the wood, but where is the victim of the whole burnt offering?'—Gen. xxii. 7."

Such was the decoration of the walls of our old churches, nor were the details or furniture neglected, but all enriched with colour, and the smaller parts with gilding. The richness produced by this treatment, which might otherwise have appeared too glaring, was chastened and softened down by the dim religious light shed through the storied panes of the stained windows, which, while they added to the general effect, imparted a chasteness throughout the whole structure. An old church in all its glory, must have been truly beautiful.

Of the materials.—Our old churches were most generally built of stone, and the majority of them of rough unhewn rag or rubble, built up into the fabric in the same state as brought from the quarry; the individual stones were small, and not all of the same size; they varied likewise in shape, not being built up in regular courses, but fitted together as neatly as circumstances would permit; the longer spaces being filled up with smaller stones, and the lesser ones with cement. This masonry was bonded at intervals by longer stones running through the work, and at the angles by coins of more regular workmanship. The dressings of the building, such as the jambs and finishings of windows, doorways, and other apertures, as well as the pinnacles, water-tables, string-courses, mouldings, and all other portions of the edifice which required much labour, were of some more manageable stone, such as Caen; and in some of the more highly embellished structures, of Purbeck marble. In some localities, flint is employed instead of rubble, more especially in Norfolk and Suffolk, not unfrequently in Essex and other counties; in many cases of this kind, the walls are made up of flints, inserted in a kind of framework of freestone, which method, with the aid of good cement, produces a very durable and not unpleasing structure. Nor are these the only materials employed in the construction of churches; we occasionally meet with brick and wood as substitutes for stone, more frequently than elsewhere, in the county of Essex. Brick, however, was not used during the best periods of ecclesiastical architecture, nor does it produce an effect so pleasing to the eye, as either of the before-mentioned materials; their colour, red, is not nearly so agreeable as the more subdued tones of flint or rubble. The walls, in all the above cases, were of great thickness, which tended not only to the greater stability of the structure, but also to maintain an equability of temperature in the interior. A good specimen of a wooden church is that of Greenstead, Essex, which has recently been restored, and of which the following description, previous to its restoration, is given in one of Weale's Quarterly Papers:—

"The timber walls, which," says the writer, "I take to be of oak, though some imagine them to be of chestnut-wood, are but six feet in height on the outside, including the sill; they are not, as usually described, 'half-trees,' but have had a portion of the centre or heart cut out, probably to furnish beams for the construction of the roof and sills: the outside or slabs thus left, were placed on the sill, but by what kind of tenon they are there retained, does not appear; while the upper ends, being roughly adzed off to a thin edge, are let into a groove, and which, with the piece of timber in which it is cut, runs the whole length of the building itself; the door-posts are of square timber, and these are secured in the above-mentioned groove by small wooden pins, still firm and strong—a truly wonderful example of the durability of British oak. At the west end I had an opportunity of examining the very heart of the timber; to the edge of an exceedingly good pocket-knife, it appeared like iron, and has acquired from age a colour approaching to ebony, but of a more beautiful brown; and if any conclusion may be drawn from the appearance of the building, I see no reason why it should not endure as long as it has already existed. The outsides of all the trees are furrowed to the depth of about an inch into long stringy ridges by the decay of the softer parts of the timber, but these ridges seem equally hard as the heart of the wood itself; the north doorway, which measures only four feet five inches in height by two feet five inches in width, is at present closed with masonry; but the aperture must have been original. It is generally thought that the woodwork of the roof is coeval with the walls, and it was most likely formerly covered with thatch, as Bede describes, and as may still be seen on many village churches in the county of Norfolk.

"The body of the church is lighted by windows in the roof, but these are decidedly of a recent date; what little light its interior enjoyed in its primitive state, was probably admitted from the east end, if any windows existed at all.

"How the interior was originally finished, cannot be now determined; at the present moment it is kept in a very neat and reputable state; its walls and ceiling are plastered and whitewashed, and its area affords sufficient accommodation for the population of the parish."

The nave is the portion of the church here alluded to, for the chancel is not of the same material, and is of a later date; the tower is also of wood weather-boarded, with luffer boards for the admission of light.

Since the above account was written, this unique little edifice has been restored, under the superintendence of Messrs. Wyatt and Brandon; and in an article on the subject, to be found in "The Builder," a short period subsequent to its restoration, the following remarks occur. The writer, in combating Mr. Suckling's opinions as to the timbers being less than half-trees, says—"We see no evidence of this, for the timbers were evidently left rough, and the dimensions prove them to have been, as nearly as may be, 'half-trees.' These uprights," he continues, "were laid on an oak sill, 8 inches by 8 inches, and tenoned into a groove $1\frac{1}{2}$ inch deep, and secured with oak pins. The sill on the south side was laid on the actual earth; that on the north side had, in two places, some rough flints, without any mortar driven under. The roof-plates averaged 7 inches by 7 inches, and had

a groove corresponding with the sill, into which the uprights were tenoned and pinned. The plates were also of oak, but they and the sills were very roughly hewn, in some parts being 10 inches by 10 inches, and in others 6 inches by 6 inches, or 7 inches.

"There were twenty-five planks or uprights on the north side, and twenty-one on the south side. The uprights in the north side were the least decayed. Those on the south side required an average of 5 inches of rotten wood to be removed, those on the north about 1 inch only, and the heights of the uprights, as now refixed, measuring between plate and sill, are on the north side 4 feet 8 inches, on the south side 4 feet 4 inches, the sills being bedded on a few courses of brickwork in cement, to keep them clear of damp. The uprights were tongued together at the junction with oak strips, and a most effectual means it proved of keeping out the wet; for although the interior was plastered, there was no evidence, in any part, of wet having driven in at the feather-edge junction of the uprights—a strange contrast to many of our modern churches, where, with all the adjuncts of stone and mortar, it is found no easy matter to keep out the driving weather from the south-west.

"The roof was heavy, and without any particular character; it consisted of a tie-beam, at less than six feet from the floor, with struts. The covering was tile."

We have given the description of this little church at so great length, because we think buildings erected after this manner would form very good substitutes for those un-ecclesiastical-looking structures termed Temporary Churches, which are become so fashionable now-a-days; and not only so, but might be even erected as permanent ones, in places where a better could not be provided.

Of symbolism.—Although many persons are so far prejudiced against the system as to deny the existence of symbolical meaning in the peculiar structure and arrangement of churches, to the unprejudiced mind there can be little doubt of the fact. It is true that some of the advocates of the system have carried it to too great a length, and have strained their point to such an extent as to appropriate a deep theological meaning to the smallest details, yet this should not hinder us from giving attention and credit to those who hold themselves within reasonable limits. This idea respecting the æsthetic character of ecclesiastical buildings, has but lately been brought into general notice, but it is no new fancy; on the contrary, we find mention of it in the writings of the early Christians. The following passage is from the Apostolical Constitutions:—"When thou callest an assembly of the church, as one that is the commander of a great ship, appoint the assemblies to be made with all possible skill; charging the deacons, as mariners, to prepare places for the brethren, as for passengers, with all care and decency. And first let the church be long, like a ship, looking towards the east, with its vestries on either side at the east end. In the centre, let the bishop's throne be placed, and let the presbyters be seated on both sides of him; and let the deacons stand near at hand, in close and small garments, for they are like the mariners and managers of the ship." As we have before remarked, the material structure of the church was from the earliest period considered emblematical of the ark of Noah. Similar allusions to that just quoted, are constantly occurring in the patristic writings; thus S. Ambrose tells us why baptisteries should be octagonal, and Clement of Alexandria gives rules by which the selection of sacred emblems should be guided; Eusebius informs us that Constantine surrounded the apsis of the church of S. Cross with twelve pillars, according to the number of the twelve apostles; and Hermas, in his visions, represents the building of the spiritual temple under figures wholly taken from the material fabric. But of all writers on the subject, Durandus is the most copious, and is held up as the highest authority in such matters. Mr. Lewis, in his description of Kilpeck church, Herefordshire, is one who has of late brought the subject of symbolism into notice; he is one of those, however, who in our opinion have laboured to apply the system to a greater extent than is warranted by facts; he enlists every portion of the fabric, even to the minutest details, to illustrate his views, and makes the arrangement of the sacred edifice to indicate the minutiæ of theological doctrine. Mr. Poole, in his lectures on church arrangement, does not attempt so much; he maintains "that ecclesiastical architecture is a language; that it has always, so long as it has deserved its name, aimed at expression; and not at mere accommodation without splendour, or even at splendour without a spirit and a meaning: that from the first it was rational; that it had a soul and a sense which it laboured to embody and convey to the beholder: that its language was not only expressive, but appropriate; that it aimed not only at accommodating a congregation, but at elevating their devotions and informing their minds." He is of opinion that the greater mysteries of our religion are symbolized in the fundamental design of the structure, while other Christian verities are set forth in the minor arrangements and in the ornamental details. For instance, the mystery of the Trinity is symbolized by the threefold division of our churches into nave and aisles, and perhaps in the longitudinal division into nave, choir, and chancel, otherwise the division into nave and chancel is said to point out the division of clergy and laity: but the æsthetic principle is more evident in our larger churches; thus in our cathedrals we have the form of the cross in the ground-plan, also the threefold division of body and aisles, as well as of nave, transept, and choir; we have likewise the same number of divisions vertically in the lower arcade, triforia, and clerestory, as also in the exterior elevation in the central and two western towers. Mr. Poole concludes—"On a review, then, of the facts mentioned, we may safely conclude, that, from the first, there has been a sufficient degree of uniformity in Christian churches, to indicate a unity of design, which could not be accidental; that the origin of that unity is to be found in the desire to symbolize the truths of our holy religion in every apt manner, and, above all, in the sacred edifices of the Christians." "A Gothic church, in its perfection, is an exposition of the distinctive doctrines of Christianity, clothed upon with a material form; and is, as Coleridge has so forcibly expressed it, 'the petrifaction of our religion.'"

As church-architecture is receiving a fair modicum of attention at the present time, and churches are being multiplied to keep pace with the requirements of a vastly-increasing population, it may not be out of place, in a work which pretends rather to useful and practical information, than to amusing recreation, to give some rules for the guidance of those who are called upon to prepare plans and designs for church-buildings.

In the first place, then, let the architect consider well the amount which is to be laid out in the erection, for this must determine every other consideration; if the amount be small, do not let him attempt a large or highly-decorative building. He must first take care to ensure soundness and strength in the construction, and leave the details to be considered afterwards; if, after calculating the cost of the mere walling and other necessary parts of the structure, he finds he has sufficient to construct them in a substantial manner, and money to spare, let him then decide upon the amount of decoration. It is better to erect plain walling, so that it be so' d and well-

build, than to add enrichment upon enrichment upon walls which are scarcely able to support them. Let strength be the object sought to be attained, not show; mere ostentatious display is quite out of character in a sacred edifice. This leads us to the next rule:—let every material employed be real; if funds are not sufficient for the best materials, use the more common, but do not attempt to hide them, let them appear what they are in reality, in their true colours, and not stain or plaster them to resemble things of a superior description; the building may not appear so rich, but it will bear the stamp of reality and truth, which will carry a conviction of its superiority to minds perhaps unwilling to yield to its demands.

Of construction.—The best material for the walling is undoubtedly stone, and of this, we suppose, that which is dressed and squared should be preferred; we do not speak with certainty in this case, for there decidedly are advantages attached to undressed, uncoursed masonry; the very unevenness imparts a richness and variety of colour to the material, and a play of light and shade over the surface, which is not attainable in an even or smooth wall; but besides this, there is another superiority in the contrast which is afforded between the naked wall and the more finished dressings of the apertures. But even if this matter be left undecided, it will make but little difference in the present day, for few architects have funds at their disposal to allow them a choice between the two. The stone best adapted for the purpose, in the practice of the present time, is rag or rubble, which is unexpensive, and at the same time durable; it may be procured in most localities without much trouble. Whatever be the nature of the stone, it is not necessary nor desirable that it be quarried in large masses, the smaller the better, so far, at least, as is consistent with a due regard to the safety and expense of construction; when the stones are large, they are apt to catch the eye, and lead it away from the more detailed portions of the building, whereas, if the separate stones be of small size, and more especially if they be of irregular outline, and random-coursed, they will render the more important features distinct and effective. For this same reason, the finished stones of the apertures, and such like, should not all be of the same size, either in length or height, so as to form a regular line at their junction, with the rubble masonry, for, if so, they will divert the attention from the main outline and decoration of the windows, &c., which the eye ought to catch at the first glance; but besides this, if the jamb-stones be of different lengths, they will form a more efficient bond with the main wall. The latter remarks will apply to all buildings, whatever be the materials of which they are composed.

With regard to the selection and laying of stones, the best plan is to use them as they come to hand, studying neither their shape nor situation too closely; a wall, constructed in this manner, will look natural, and therefore far better, than when the stones are broken or placed in a peculiar manner for the sake of appearance. In no cases attempt to make the joints over close. The dressings will of course be formed of a stone which may be easy to work: Caen is a good stone for the purpose, but if this is not to be obtained, some kind of freestone may be discovered in the neighbourhood, available for such service. The nature of the stone required will vary of course with the degree of carved enrichment to which it is to be subjected.

Where flint is abundant and more readily procurable than other kinds of stone, it may be used with advantage, as is evidenced by many an old structure. Care should be taken that it be well bonded and cemented together, otherwise it will not be so secure as rubble masonry; in some cases, which we have before alluded to, the walls are formed of a sort of frame-work of freestone, the intermediate spaces being filled in with small squared flints. In new work the effect of flint is not so good as could be desired, but it improves by age; the contrast between it and the freestone being modified in process of time; old buildings of this material have a very pleasing effect.

If none of the above materials can be procured without much difficulty, brick is not to be discarded, although not to be recommended unless under peculiar circumstances. If you are compelled to use it, do not attempt to disguise it by stucco, a brick church is better than an imitation stone one; plaster may be used occasionally to preserve a wall, but, if so, let its nature and its purport be at once evident. Churches of red brick are to be found in Essex, but they are of a late period, and are not to be imitated unless absolutely necessary. In general cases, rag or rubble is preferable, not only in appearance, but even in economy.

Timber, though by no means a desirable material, may in special cases be employed. A church of this description has already been noticed and described, it will therefore be unnecessary here to enter into a consideration of its construction. While upon this subject we cannot conclude without again suggesting, whether churches built after the fashion of that at Greenstead, above described, would not be more appropriate structures for temporary churches, than those which at the present day pass under that denomination.

In all the above cases, let the walls be of considerable thickness, as this tends not only to the security of the structure, but also, as we have said before, to the preservation of an equable temperature in the interior.

Of the covering.—The best covering for the roof is lead, of sufficient thickness—7lb. lead is a good quality—but it has its disadvantages; in the first place it is expensive, and therefore not suitable for the present time; it also requires great care in laying, and unless pure, and of good quality, is liable to corrode. Slates are not objectionable if they be of a good colour, but the common blue slate does not harmonize well with the masonry; very fair specimens are to be procured from the north of England. Tiles and thatch are frequently found on old churches; the former may be employed, but the latter is objectionable, for reasons which will be obvious to every reader. Rag-stones may be used for the purpose, as may also shingles; the latter are eligible on account of their lightness, and other qualities, but they are not secure against fire.

Of the internal wood-work.—The roof, benches, screens, and other wood-work should be of oak, if expense is no obstacle; however, fir, walnut, and other inferior timber, are more generally employed now-a-days; but whatever is used, it should not be stained or grained, to resemble wood of a superior quality; it may be prepared in any manner which will tend to its preservation, and in this way its appearance may sometimes be improved. Deal may be employed when the funds will not admit of a better substitute. Varnish is now frequently used, but we think it better avoided; at least, allow it a sufficient time to dry, before the church is to be used for service.

Of the flooring.—The best materials for paving the floor are encaustic tiles, ornamented in appropriate-coloured devices; plain tiles, however, will answer very well for the nave, they should be placed diamond-wise, the alternate ones being of the same colour with a differently-coloured one between; red and black are the common colours. The enriched encaustic tiles may be judiciously reserved for the chancel; plain tiles are well introduced even here, for they serve as a contrast, as also to throw out the patterns of the richer sort.

Of metal-work.—The metals are used for a variety of pur-

poses, the more costly in the furniture of a church, but we shall here confine ourselves to the ornamental iron-work, used for hinges, locks, bars, and such like, many beautiful specimens of which are preserved to us in our old churches. We must, at starting, lay down, as a rule, that iron, for these purposes, should be wrought, not cast; the latter class of iron-work is always a failure. These ornaments should not be painted, but, to preserve them from rust, it is recommended that they be dipped when red-hot in grease, and left to cool; the same purpose will be answered by coating them with some incorrosive metal.

Of style.—The best style for adoption in parish-churches is undoubtedly the Decorated, from the middle of the thirteenth to the middle of the fourteenth century. During this period Christian art was at its perfection, and soon after began to lose its character for genuine simplicity; the introduction of the depressed arch, and the excessive embellishment of the later style, was the commencement of its downward course. We would not, however, confine the architect to a single style; Early English is well adapted for large churches, and may occasionally be made available for smaller ones, while Perpendicular is appropriately employed for churches in cities and large towns, sometimes even with greater advantage than Decorated, which is particularly the case when a church, being closely surrounded with other buildings, requires large windows on those sides which are more open to the light. For the generality of churches, however, the Decorated is by far the most suitable, it is equally adapted for a plain, as for a more highly-finished structure, and has a natural grace which ensures its perfection, in whatever situation it be placed; it will admit of the highest elaboration, so far at least as is consistent with purity, or of the plainest construction, without sacrificing any of its inherent beauties; on the other hand, the Perpendicular style must be highly enriched, or otherwise it will appear meagre, and is therefore unsuitable, except for an expensive edifice. We have said nothing of Norman, but we must not pass it over in silence; it is decidedly not so appropriate as any of the above-mentioned styles for parish-churches, and yet we should be sorry to see it entirely discarded; it must not be recommended, but it has its peculiar beauties, which doubtless will always secure to it some share of public favour.

Of the plan.—The amount of money at the disposal of the architect, as it determines the material to be employed, will likewise, to a certain extent, govern the size, and therefore the plan and arrangement of the building. The ground-plan will also depend, in a great measure, on the site allotted for the building. For very small churches, the best arrangement is the most simple, viz.; that of the parallelogram, divided into nave and chancel, which division need not be shown on the exterior, although it is very desirable that it should be so, and in this case the chancel is marked by its smaller dimensions in height and breadth; the chancel should always be separated from the nave in the interior by an open screen of wood-work, as also by being elevated on one or more steps. An important and inexpensive addition may be made to this plan in the shape of a porch, which may be either of wood or stone, and should be placed, unless there be any strong reason to the contrary, towards the western end of the south side. A further improvement will consist in the erection of a bell-turret, or gable, either on the western gable, or on that between the nave and chancel; this again need not be expensive, in some cases it may be made of wood, in which material we have a sufficiency of ancient examples; but it is best, of course, of stone; of whichever material it be constructed, it always forms a very marked and beautiful feature in a small church. We should be rejoiced to see a larger number of such small structures as the above erected at the present day, when all seem to aim at an edifice of much greater pretensions, even though they have, it may be, scarcely sufficient funds for the erection of one of the more simple structures in an efficient manner. Towers placed between the nave and chancel are not unfrequent in some parts of England.

If accommodation for a larger number of worshippers be required, one or more aisles must be added to the nave. A nave with two aisles is the perfect form, but both aisles need not be built at the same time, unless the number of the congregation require it, and there are ample funds for its erection. At the same time, never build only one aisle for the sake of appearing extraordinary, nor unless there is an intention of erecting a corresponding one at some future period; for this reason, when a single aisle is adopted, let the opposite wall of the nave be built with arches of construction, so that when the second aisle is added, it may be necessary only to remove the masonry between the arches. This last method might be adopted with advantage in the first class of churches. We may remark here, once for all, that it is by no means necessary that the opposite sides of a church should exactly correspond.

This last is the most eligible form of structure for ordinary churches, to contain, say from two hundred persons and upwards. For churches of this capacity the first-mentioned form is not adapted, as, when so large accommodation is required, you would be compelled to extend the nave to an inconvenient breadth; twenty-five feet is the greatest dimension allowable in a small church without aisles; when aisles are added, their breadth, as a general rule, should be to that of the nave in the proportion of two to five, but this ratio is not fixed, it varies in different examples.

If still greater accommodation be required, it may be obtained by continuing the aisles on one or both sides of the chancel, from which they should be shut off by parcloses of open work; but this addition is not a desirable one, and should be adopted only in such places as the architect is cramped for room. A more legitimate method of obtaining greater space in general instances is by annexing a tower, which should open into the church by a lofty arch. This, though not essential to a church, forms one of the most striking and picturesque features, and when the means will admit of it, should never be omitted; though, on the other hand, the essentials should in no case be sacrificed to obtain it.

Of the position of the tower.—The standard situation of the tower is at the west end of the nave, although there are very many exceptions to this position, amongst which are the following, instances of which are given by the Ecclesiological Society:—west end of either aisle; middle or east end of either aisle; north or south of chancel; north side of a second north aisle; north or south side of nave; north-west and south-west angle of nave; north-east or south-east of nave; middle of nave and western end of the chancel. All these positions are allowable, when circumstances require the tower to be so placed; as a general rule, however, we think it advisable to retain it at the west end of the nave. At one time architects restricted themselves entirely to this rule, however more eligible any other situation might have been; now, on the contrary, it is the exception to see the towers in this position. We think both at fault, the former following one arrangement too closely, simply it would appear for the sake of preserving an exact correspondence in both sides of the building, even at the risk of losing other advantages; while the latter seek out extraordinary positions merely for the sake of their novelty, and for the purpose of exciting surprise. The nature and shape of the ground, as well as the internal

arrangement, should decide the question. In cruciform churches the proper location of the tower is over the intersection of nave and transept, but in addition to other positions, the following are satisfactory—at the north end of the north, and the south end of the south transept. Sometimes, though rarely in this country, we find the tower detached from the church, similarly to the campaniles of the Continent.

A tower can scarcely be said to be perfect without a spire, and in churches in which the earlier styles are adopted, this feature should never be omitted; in the Perpendicular it is not of so great consequence, though even then desirable. Spires need not always be carried up to a great height, although the loftier the better, nor need they be invariably of stone, those made of shingles are very beautiful objects in rural districts, and those covered with lead or slates are not to be despised; in some counties we find both tower and spire constructed of weather-boarding. In passing, we cannot help noticing, that in many of our modern churches, the towers have not sufficient breadth, which gives them an appearance of poverty and meagreness. We suggest, whether it would not be better, where towers are deemed necessary, to lay the foundation of a more substantial structure, and to leave it incomplete until the requisite funds are provided. Our old church-builders always went to work on this principle, which accounts for the single aisle, and many other irregularities, as, for instance, difference of style in the different portions of a church. This plan might be carried out with advantage in the present day, not only in the larger parts of the structure, but also in the finishing of details, &c. The plan of the tower is generally square or rectangular, supported at its angles by massive buttresses, which add greatly to its appearance; not unfrequently a turret, containing a staircase, is added at one angle, which affords a picturesque irregularity, especially if it be carried up above the main building; this is particularly the case in the later styles.

Another addition which will be required, is the sacristy or vestry; its position should be on the north side of the chancel, with which it should communicate by a door: it should never be of large dimensions or imposing design. This is the only part of a church where a chimney is allowable.

Up to this point we have made scarcely any mention of cruciform churches, not because we do not think this a beautiful form, but rather because it is ill adapted to present circumstances. Such a plan is doubtless the most expressive of any for a Christian church, but it is not the most economical; it does not economize space. It is true the cross arms may be used for the accommodation of worshippers, but not without great inconvenience; persons placed there will not be, as it were, with the rest of the congregation, they must look a different way, and not only so, but must be hid from the altar and the greater portion of the performance of the services; in fact, transepts were not intended for this purpose, as is evident by there being seldom found any seats in this position, and even when such are seen, they are mostly subsequent additions. Besides all this, the cross form is more expensive in construction. When funds are ample, transepts may well be added, but not otherwise.

Of apertures.—These consists of doors and windows, and to both of them one remark will apply: do not make them too large; for with respect to the former, it may be said that they are seldom made an important feature in English architecture, not even in our cathedrals; and as regards the latter, small windows are advantageous on many accounts, not only are they more unassuming than larger ones, but they answer the present times—when stained glass throughout the building is scarcely to be looked for—by admitting less light, and if stained glass is to be inserted, they require but a small quantity. A great mistake, in our opinion, is very generally made in the present day, in allowing too great an area for lighting a church, either by making the windows too numerous, or too large; a glare of light is not desirable in a church, it interferes with people's devotion; we want a subdued tone, that "dim religious light" which was admitted of old through the stained windows, and this is to be procured rather by diminishing than increasing the area admitting light. With reference to the position of doors, there should be one small one for the priest in the south side of the chancel, another at the porch, and a third, generally speaking, opposite the last; in transeptal churches, there may be one at the west end, and another on the west side of one of the transepts.

We have previously hinted, that it is not at all necessary that the corresponding parts of the building should be in every respect uniform: the same remark holds equally true as to detail, as it does in respect of the main features of construction; the windows and other apertures need not be placed at exactly the same distances apart, nor is it necessary that the windows on both sides of the church should in every particular correspond; a buttress should not be placed between every two windows, or at every corner of the building, merely for the sake of appearance, nor indeed should they be employed at all, unless requisite. The governing principle in such matters, should be to use nothing more than is wanted, and place things just where they are required; if this rule were attended to, it would save a vast deal of unnecessary trouble, and produce in the end a far more satisfactory, because more natural, appearance. "How often do we see," says a writer for the Ecclesiological Society, "a simple village church, consisting of low and rough stone walls, surmounted, and almost overwhelmed, by an immense roof, and pierced with some two or three plain windows, between as many bold irregular buttresses on each side; or having a short massive tower placed at one angle, or in some seemingly accidental position, which nevertheless every one confesses to be as picturesque, and beautiful, and church-like an edifice as the most critical eye could wish to behold! while a modern design, with all its would-be elegancies of trim regular buttresses, parapet, and pinnacles would cost twice the money, and will not look like a church after all. Here perhaps one half of the money is laid out first in procuring, and then in smoothing and squaring great masses of stone, or in working some extravagant and incongruous ornament; whereas the small and rude hammer-dressed ashlar or rubble work of the ancient model, has a far better appearance, and allows a larger expenditure where it is most wanted, in the arrangements of the interior."

This leads us to remark, that the interior should be the main object of consideration, and should never be sacrificed to make way for a showy exterior, although this is too frequently the case with modern churches; it was far different with our ancestors. Of the interior, the chancel is that part on which the architect's best attention should be given. The interiors of our old churches, as we have previously stated, were enriched in the most splendid manner, all the finest productions of art were lavished upon them, the sculptor and painter vied with each other in their decoration—and why should it not be so now? Surely paintings in fresco would be preferable to yellow-ochre and whitewash, nor do we see any moral objection to pictorial representations in our churches, there can be no fear of people worshipping pictures now-a-days, the greater fear is for the want, not the excess, of reverence; they are the books of the unlearned, and serve not only to instruct the ignorant in matters which they would not otherwise know, but also bring before the attention of

the more learned, things of which otherwise they might be forgetful. But if objections still be urged against the employment of the painter's highest branch of art, surely there can be no exception brought against such decoration as we have described as occurring at Luton Church. The employment of texts of Scripture delineated on the walls, is sanctioned by the order of the church, when she enjoins in her eighty-second canon—"That the ten commandments be set up on the east end of every church and chapel, where the people may best see and read the same: and other chosen sentences written upon the walls of the said churches and chapels, in places convenient." Passages of Scripture well selected and appropriately arranged, would form at the same time, a very useful and beautiful appendage to the walls of our churches; though, as we think, scarcely equal to the more pictorial illustration advocated above. We should be glad to see the interior of our places of worship relieved from the coldness which ever hangs about bare walls; let at least some coloured decorations be introduced into the chancel, if nowhere else.

Of the roof.—Open roofs, those in which all the beams and rafters are visible, should of course be adopted, the use of ceiling is now almost quite exploded; roofs of this kind not only afford an appearance of greater height to the building, but also have a perspective effect, by the repetition of the same parts, which adds to the apparent length of the church; indeed, the same building covered at one time with an open roof, and at another with a flat ceiling, would present two such very different aspects, as scarcely to be recognized as identical. Various forms may be used, of which, whether rich or simple, beautiful ancient examples are to be found; in small churches, where the span is inconsiderable, the arched form may be used with advantage; the amount of trussing increases of course with the span. Tie-beams are scarcely admissible, as they detract from the aspiring principle developed in church architecture, and arrest the eye in its progress upwards; they have in a small degree the same effect as a flat ceiling; there is, however, seldom occasion for their employment, they are not requisite in a high-pitched roof, especially where the walls of the building are of considerable thickness; the thrust is rather vertical than horizontal.

Of pews.—Let all the seats be low open benches with low backs, the lower the better, as far as convenience will allow; for as the height increases, so must the distance from each other; if this circumstance be not attended to, the high back will be found to be in the way: a convenient height is two feet six, preserving the same measurement between every two seats. The benches must be arranged across the church so as to face the east, and in such a manner as to allow of easy access to every part of the church; for this purpose, there should be a main passage running along the centre of the nave, five or six feet wide, and another of the same measurement across the church, connecting the north and south doors; smaller passages are necessary along the aisles, and at the east end of the nave. In small churches, the standards at the ends of the seats should be of a plain character, but in the larger ones they may be carved and finished at the top with poppy heads, &c.

Of galleries.—Galleries should on no account be admitted into a church; they entirely spoil its appearance, cutting up windows, and sometimes pillars, into two or more pieces, hiding the roof, marring the proportions, and obstructing a fair view of the interior: they are noisy, ill-ventilated, and clumsy, and not only are they ill-ventilated themselves, but they interfere with a proper circulation of air in the aisles beneath them, and by their principle of over-crowding a church, assist materially in vitiating the air throughout the building. And what is the advantage proposed to be effected by them?—the economizing of space, that is, the obtaining an increase of accommodation at a small expense: but do they effect this object? decidedly not; the additional space obtained by their adoption is very trifling, for from the total area of the gallery must be deducted, not only the main passage leading at the back of the seats throughout its length, but also the numerous cross passages branching from it to afford convenient access to the different parts of the gallery, so that, in fact, in the majority of cases, a full third, and in some instances nearly one half of the area obtained, is lost in passages of communication; add to this the space occupied in the aisles, by the piers or other supports, and it will be evident that the advantages in point of accommodation are very small. When, bearing all this in mind, we consider that the walling is frequently carried up to a greater height than otherwise necessary, for the sake of introducing a gallery, we shall scarcely be prepared to defend such *excrescences* on the score of economy.

Of the principal furniture.—The first object which needs a few remarks is the font; it should invariably be of stone, as ordered by the church, and of a size sufficient for the immersion of infants; there should be a drain leading from the bottom of the bowl down into the earth, to carry off the water used in the service, and the bowl, when not in use, should be protected by a cover. The situation of the font must be near the entrance in the nave, and should have sufficient space left round it for the priest, sponsors, and others immediately concerned in the rite. The pulpit, which may be of wood or stone, should be at the south-east or north-east end of the nave, either detached or built up with the wall or pier, and should not be elevated at too great a height: if there be a choice of situation, the north side of the nave is the preferable position. We need say nothing in this place respecting the furniture of the chancel, as it has already been described under that title; we may only add that we should be glad to see the whole of it introduced into our modern churches, even to the rood screen, which is so much objected to by some, on account of its being, as they say, a Romish invention, whereas in fact it has been employed in the Eastern as well as the Western church, from the very earliest period.

Of the lighting, warming, and ventilation of churches.—The best method of lighting a church is by candles, which may be held either in standards fixed or moveable, or ir chandeliers made after the pattern of the ancient *coronæ lucis.* Gas is cheaper than wax-lights, we are aware, but a trifling additional expense should scarcely be a consideration in such a matter; besides, amongst other disadvantages, the glare of gas-lights is but ill adapted to the solemnity of a church, and the heat emitted from them is oppressive and somniferous. A fire-place is hardly admissible into a church, and stoves, hot air or water pipes, should never be attempted, they are unsafe, as well as unhealthy. The best method of regulating the temperature of a church, is by building substantial walls, and efficient drains, allowing a free circulation of air, and keeping the whole building in good and proper repair. If low benches, and high-pitched open roofs be adopted, while galleries and gas-lights are at the same time discarded, there will be little difficulty as to ventilation.

Of the restoration of churches.—Little need be said on this head. the main point to be attended to is, the reducing the building as nearly as possible to its original state, in structure, arrangement and decoration; it most frequently happens, that the minutiæ of the old structure are not traceable, and in such cases the judgment of the architect is called into action, but where the old arrangement is perceptible, it should always be

followed in the restoration. The first thing to be attended to is the drainage, many old churches being destroyed by damp; in very many cases the earth of the church-yard will be found to have accumulated to a considerable height above the floor of the church, and this of course should be at once removed, and a proper ventilation given, to dry the foundations. The interior walls should be carefully cleansed of the many coats of whitewash, so that, in case any vestiges of painting remain, they may not be destroyed for want of proper caution; the same care should be taken in removing the plaster and whitewash from the ornamental details; flat ceilings likewise should be removed with caution, as they were frequently added merely to hide existing defects in the roof. Structural restoration should be first attended to, after that the arrangement, and lastly the decoration.

Of the enlargement of churches.—Architects are not unfrequently called upon to afford increase of accommodation in old churches; it may therefore not be out of place to point out as briefly as possible how this may be best effected. The first step is to calculate how much additional accommodation may be obtained by a proper re-arrangement of the seats, and a substitution of low benches in the place of the modern pews, and to regulate for further additions accordingly. Churches in which additions are advisable, are the following: those which consist only of nave and chancel, which may be enlarged by the addition of one or more aisles to the nave, and of a tower, if requisite;—those consisting of nave, chancel, and one aisle, where accommodation is naturally increased in completing the church by the addition of an aisle on the opposite side of the nave, an addition frequently contemplated by the founders, as is manifested by the existence of arches of construction in the nave-wall;—those again consisting of a nave and chancel, with tower between the two, may be enlarged by adding transepts, which, in cases of necessity, may be used for worshippers. Of churches comprising a nave with two aisles, a chancel and a tower, increased space may be obtained by a continuation of the aisles to the extremity, or nearly the extremity, of the chancel, or by adding another aisle to the nave. Either of these plans may be adopted in cases of great need, but they are by no means to be recommended; in both cases the same objection holds, that the people are packed into situations which are not convenient for public worship; in the first case they are made to look in a different direction from those in the body of the church, which interferes with the apparent unity of the worshippers, and, in the latter, a great portion of them are excluded from a proper view of the chancel. In such cases it would be much more advisable to erect a new church or chapel, however small or unimposing, but this necessitates other expenses, and is not always practicable; where it is possible, it should be adopted in preference. The Rev. J. L. Petit, in his Remarks on Church-Architecture, recommends additions to the chancel to be made in almost all cases where enlargement is required; but we must differ from him in this matter, for, be it remembered, that in our old churches, these projections were not used by the congregation, but were employed as side-chapels; in fact, their existence is attributable to the corruptions of the church of Rome: such additions may be used for the location of the organ, or such like purposes, but not, if avoidable, for the accommodation of worshippers. In other churches where none of the above methods are available, it is better not to attempt enlargement; the lengthening of the nave is a poor expedient, which may at once destroy the proportions and mar the unity of the original design.

We here take leave of a subject which we are rejoiced to say is daily receiving increased attention. Some few years since, our ecclesiastical structures were looked upon as remnants of by-gone days, to be wondered at for their associations and antiquities, but scarcely to be imitated in modern times but of late a new light has appeared, infusing spirit and animation into the old buildings, and we no longer look at them as the relics of a barbarous age, but as examples most fitting to be followed in all sacred structures; they formed once the lore of the antiquarian, they are now the models of the architect. It is a matter of wonder how rapidly knowledge, on this subject, has been acquired; it is as yet imperfect, but is progressing satisfactorily; fresh discoveries are being made continually, and ere long we shall have a goodly number of useful text-books on the subject. We must not forget, that the first impulse in the right direction was afforded by the Cambridge Camden Society, to which the gratitude of every lover of our old parish-churches will be readily accorded. We have now Architectural Societies of a similar kind established all over the country, to which, in conjunction with the labours and researches of private architects, we look for a great increase of information. An additional incitement to this study has been given by the erection of so many churches in various parts of the country, in most of which a vast improvement may be observed on buildings of a similiar kind erected in previous years; it is true they are not all, perhaps but few, without faults, many of them are faulty in numerous respects, yet, as a whole, they are very satisfactory; we cannot do better in concluding this article, than repeat the remarks of Mr. Petit on the progress of church-architecture, and the impediments which the professional man has to encounter in its advancement. "So great," says he, "are the actual and inherent difficulties of his art, and so grievously are they multiplied by external causes, so limited and restricted is he by the perverseness of others, so many conflicting tastes and opinions has he to consult, so beset is he on every side by the ostentatious views of one, the parsimony of another, the private interests of a third, and the overweening ignorance of the greater number, that it is a marvel his work should ever be respectable; and we cannot deny that many of our modern churches are extremely creditable to the taste and skill of their designers. Let those who speak of the labours of the architect with flippancy, or censure them with unkindness or severity, reflect upon the difficulties he has to encounter; of no other art are the principles and beauties more deeply hidden in the treasury of nature, and to be searched out with greater toil and diligence."

CHURCH-HOUSE, a building in which meetings were held for the transaction of church matters and parish business; it was sometimes a room situate over the porch.

CHURCH-YARD, the space of ground surrounding the church, used as a cemetery or burial-ground. The entrance to our old church-yards was frequently through a gate covered with a projecting roof, called the lych-gate, under which the coffin was rested before entering the ground; and opposite the porch, was a lofty stone cross elevated on one or more steps, and frequently adorned with the emblems of the Evangelists, and other enrichments. Near the cross was planted a yew-tree, whose boughs were carried in procession on Palm Sunday, and used at other times to decorate the interior of the church.

The unwholesome practice of interment in towns is being discontinued, and consequently the church-yard in such cases is in a great measure dispensed with; where practicable, however, the church should be contained within a walled enclosure. The best model for an extra-mural cemetery, is that lately planned at Oxford: cemeteries are usually objectionable, on account of being made the subjects of speculation and pecuniary profit.

CIBORIUM, in ecclesiastical antiquity, the covering of an altar; being an insulated edifice, consisting of four columns supporting a dome. The ciborium was used during the lower and middle ages; but was afterwards superseded by the baldachin. *See* BALDACHIN.

The most magnificent ciborium ever known, was that erected by Justinian, in the church of St. Sophia, at Constantinople. It consisted of four large red marble columns, supporting a silver dome, surmounted with a globe of massy gold, weighing 118 pounds, and surrounded with lilies of gold, falling in festoons, weighing 116 pounds; and in the middle was a cross of the same metal, weighing 75 pounds, covered with the most rare and precious jewels.

CILERY, the drapery or foliage on the heads of columns.

CILL. *See* SILL.

CIMA. *See* SIMA, MOULDINGS.

CIMA-INVERSA. *See* SIMA-INVERSA, MOULDINGS.

CIMA-RECTA. *See* SIMA-RECTA, MOULDINGS.

CIMBIA, a fillet, string, list, or cincture.

CIMELIARCH, in English churches, the room where the plate, vestments, &c. are kept.

CINCTURE, or CEINCTURE, an annular fillet, of a cylindric surface, at the ends of a column, connected to the shaft by the apophyge, or scape. The cincture at the top of the column, is named also collarino.

CINQUEFOIL, an ornament in the pointed style of architecture, consisting of five cuspidated divisions, or curved pendants, inscribed in a pointed arch, or in a circular ring, applied to windows and panels. The cinquefoil inscribed in a circle, is a rosette of five equal leaves, with an open space in the middle; the leaves being formed by the open spaces, and not by the solids or cusps.

CIPPUS, a small low column, sometimes without a base or capital, and most frequently bearing an inscription. The cippus was used for various purposes among the ancients: when placed on a road, it indicated the distances of places: in other respects, the cippi were employed as memorials of remarkable events, as landmarks, and for bearing sepulchral epitaphs. Also the prison of a castle.

CIRCLE, (from the Latin, *circulus*), a plane figure contained under one line, called the circumference, which is such that all lines drawn to it, from a certain point within the figure, are equal; and the point from which the lines may be thus drawn, is called the *centre of the circle.*

A circumference may be thus described: if the end of a right line be placed upon a fixed point, and kept upon that point while the other end is carried progressively forward, or round, until it comes to the place whence the motion began, the moveable extremity will thus trace out the circumference of a circle.

In order to obtain the measurement of angles, the circumferences of all circles are supposed to be divided into 360 equal parts, called *degrees;* each degree is supposed to be divided into 60 equal parts, called *minutes;* each minute is divided into 60 equal parts, called *seconds;* each second is supposed to be divided into 60 equal parts, called *thirds;* which are again divided and subdivided *ad infinitum.* Any denomination, whether of degrees, minutes, or seconds, &c. is known by a peculiar character, written over the right-hand figure of that denomination; thus, °, written over the right-hand figure of a number, shows that number to represent degrees; the character thus, ′, written over the right-hand figure of a number, shows the number thus distinguished to represent minutes; *e. g.* $136° 24' 48'' 57'''$, &c. represents 136 degrees, 24 minutes, 48 seconds, 57 thirds, &c.; and, as similar arcs are such as are contained under the same, or equal angles, they contain the same number of degrees, &c., the number of parts of the arc of a circle, described from the meeting of two lines forming an angle, and comprehended between them, is the true measure of the angle; for the number of parts is still the same, whatever be the radius of the arc, or of the circle, the parts being greater as the radius is greater. The arc of the circle being supposed to be divided into 360 equal parts, the radius will be found to be equal to the chord of 60; because the circle contains six equilateral triangles, whose bases are chords to the circle, whose summits meet in the centre, and whose sides are radii to the circle. And since the sixth part of 360°, or of a whole circle, is 60°, the chord of 60 is therefore equal to the radius. The parts of the arc may be measured by parts of the radii, which are always supposed to contain the same number: for if there be two arcs described from the angular point of an angle, between the legs, these arcs may be measured in parts of their respective radii.

The circle is the most capacious of all plane figures; that is, it contains the greatest area under equal perimeters, or has the least perimeter enclosing the same area.

The area of a circle is equal to the area of a triangle, the base of which is equal to the circumference, and the perpendicular equal to the radius, and consequently equal to a rectangle, whose breadth is equal to the radius, and the length equal to the semi-circumference.

Circles, like other similar plane figures, are to one another as the squares of their diameters.

The ratio of the diameter of a circle to its circumference. has never been exactly ascertained. Archimedes was the first, in his book *De Dimensione Circuli,* who gave the ratio in small numbers, being that of 7 to 22, which is still the most useful for practical purposes. Vieta carried the approximation to ten places of figures, by means of circumscribed and inscribed polygons of 393,216 sides, showing the ratio to be as 10,000,000,000 to 31,415,926,536 nearly, the circumference being greater

than 31,415,926,535

but less than 31,415,926,537

Van Colen carried the approximate ratio to 36 places of figures; which number was recalculated and confirmed by Willebrod Snell. Mr. Abraham Sharp extended the ratio to 72 places of figures, which was afterwards extended to 100 places by the ingenious Mr. Machin; and, lastly, M. De Lagny, in the *Memoires de l'Acad.*, 1719, has carried this ratio to the amazing extent of 128 places of figures.

In approximating the circumference or area of a circle from the diameter, the first authors had recourse to inscribed and circumscribed polygons; since it was found that the circumference of the circle was greater than the perimeter of the inscribed polygon, but less than that of the circumscribing one; and, that when the polygon contained a great number of sides, the circumference of the circle did not differ materially from either, it would be still more nearly equal to the arithmetical mean of the two. And, to give the reader an idea how very near the circumference obtained by this means is to the truth, the circumscribed and inscribed polygons may be taken of such a number of sides, as that their perimeters will be each expressed by any given number of figures of the same value, from unity, either taken individually, or as a whole number, and consequently the circumference of the circle may be expressed, or carried to any degree of accuracy required.

But the method of obtaining the circumference by this means, being found extremely laborious, other methods, by a series of fractions, have been invented, so as not only to be much more easy in the calculation, but also to show how the terms may be continued at pleasure, by inspection

only. Dr. Wallis was the first who expressed the area of a circle, in terms of the diameter, by an infinite series, and showed that, if the square of the diameter was 1, the area would be

$$\frac{3 \times 3 \times 5 \times 5 \times 7 \times 7}{2 \times 4 \times 4 \times 6 \times 6 \times 8}, \text{\&c. or } \frac{9}{8} \times \frac{25}{24} \times \frac{49}{48}, \text{\&c.}$$

Other series were also found by Lord Brounker, Sir Isaac Newton, and Dr. Gregory. The most convenient forms of expressing the circumference, are shown in the following statement, where c represents the circumference, the diameter being unity:

$$c = 4 \times \left(1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \frac{1}{9} - \frac{1}{11} + \frac{1}{13}\ \frac{1}{15}, \text{\&c.}\right)$$

$$c = \sqrt{12} \times \left(1 - \frac{1}{3.3^1} + \frac{1}{5.3^2}\ \frac{1}{7.3^3} + \frac{1}{9.3^4}, \text{\&c.}\right)$$

$$c = 8 \times \left(\frac{1}{1.1.3} + \frac{1}{1.3.5}\ \frac{1}{3.5.7} + \frac{1}{5.7.9}\ \frac{1}{7.9.11}, \text{\&c.}\right)$$

$$c = 8 \times \left(\frac{2}{3} - \frac{1}{5} - \frac{1}{4.7} - \frac{1.3}{4.6.9}\ \frac{1.3.5}{4.6.8.11}, \text{\&c.}\right)$$

$$c = 4\sqrt{2} \times \left(2 \times \frac{1}{3} - \frac{1}{2} \times \frac{1}{5}\ \frac{1}{4.2^2} \times \frac{1}{7} - \frac{1.3}{4.6.2^3} \times \frac{1}{9} - \frac{1.3.5}{4.6.8.2^4} \times \frac{1}{11}, \text{\&c.}\right)$$

$$c = 4 \times \left(1 - \frac{1}{2} \times \frac{1}{3} - \frac{1}{2.4} \times \frac{1}{5} - \frac{1.3}{2.4.6} \times \frac{1}{7} - \frac{1.3.5}{2.4.6.8} \times \frac{1}{9}\ \text{\&c.}\right)$$

One of the most useful properties of a circle is that when two straight lines, or chords, cut each other, the rectangle of the segments of the one line is equal to the rectangle of the segments of the other line. This property may be very conveniently applied to finding the centre of the segment of a circle, or the length of the radius, the chord and the versed sine of the arc being given. The rule is as follows: Divide the square of the half chord by the versed sine, add the versed sine to the quotient, and half the sum is the radius of the circle.

The diameter of a circle being given, to find the circumference: say, As 7 is to 22, so is the diameter to the circumference nearly. This rule will be sufficiently accurate for the most practical purposes; but if greater accuracy be required, multiply the given diameter by 3.1416, and the product will be the circumference, or very near. When the circumference is given to find the diameter, divide the circumference by 3.1416, and the quotient will be the diameter. Or, say, As 22 is to 7, so is the circumference to the diameter.

To find the length of an arc, the radius and number of degrees being given, say, As 180, the number of degrees in a semi-circle, is to the number of degrees in the arc, so is 3.1416 times the radius to the length of the arc. When the chord of the arc, and the chord of half the arc are given;—Subtract the chord of the arc from eight times the chord of half the arc, and divide the remainder by 3, which will give the length nearly. When the chord and versed-sine are known;—Firstly, find the diameter, from which subtract the versed-sine multiplied by .82, and divide the remainder by $\frac{2}{3}$ of the versed-sine; add 1 to this quotient, and multiply by the chord, which will give the length of the arc.

The area of a circle, whose diameter is unity, has been found to be .7854 nearly; and since the area of a circle is as the square of its diameter, the areas of all circles will therefore be ascertained by the following rule: Multiply the square of the diameter by .7854, and the product will be the area of the circle.

But it may sometimes appear, that the circumference only can be ascertained, the diameter being inaccessible: in this case, also, the areas of circles are as the squares of their circumferences. It has been found, that when the circumference of a circle is unity, the area of the circle is .07958. Therefore the rule may be thus: Multiply the square of the circumference by .07958, and the product will be the area of the circle nearly.

Though either the diameter or the circumference is sufficient to find the area of the circle, yet, if the dimension of each can be easily ascertained, the operation of finding the area is much shorter. This may be done by multiplying the radius into the semi-circumference; the product will be the area.

By this rule, the standard area, when the diameter or the circumference is unity, as in the two preceding rules, will be easily ascertained, by halving the ratio of the diameter 1 to the circumference 3.1416: for,

2)3.1416
———
1.5708 half the circumference.
.5 half the diameter, or the radius.
———
.78540 the area of the circle by the last
———

rule, when the diameter is unity.

Again, when the circumference is unity, the diameter will be found to be .31830 nearly.

Then, .31830 ÷ 2 = .15915 the semi-circumference,
and 1. ÷ 2 = .5 the radius.

Therefore .15915 × .5 = .079575 or .07958 nearly.

To find the area of a sector, when the number of degrees in the arc are known; say, As 360, the number of degrees in the whole circle, is to the number of degrees in the arc of the sector, so is the area of the circle to the area of the sector. When the radius, and the whole or half the length of the arc are given; multiply the diameter by the arc of the sector, and divide the product by 4; or multiply the radius by half the length of the arc; in either case, the result will be the area of the sector.

To find the area of a segment. Having found the area of the sector, subtract from it the area of the triangle, when the segment is less than a semi-circle, and add, when greater, or; Divide the cube of the versed-sine by twice the chord, and add the quotient to two-thirds of the product of the chord and versed-sine.

As we must necessarily frequently recur to the subject of this article hereafter, we think it convenient to refer the reader for further information thereon to GEOMETRY, PERSPECTIVE, &c.

CIRCULAR ROOFS, are those roofs whose horizontal sections are circular.

CIRCULAR WINDING STAIRS, are such as have a cylindrical case, or walled enclosure, with the planes of the risers of the steps tending to the axis of the cylinder.

CIRCULAR WORK, a term applied to all work with cylindrical surfaces.

CIRCULAR-CIRCULAR, or CYLINDRO-CYLINDRIC WORKS, whatever work is formed by the intersection of two cylinders, whose axes are not in the same direction. The line formed by the intersection of the surfaces, is called by mathematicians, *a line of double curvature.*

CIRCUMFERENCE, the curve-line by which the area of a circle is bounded.

CIRCUMFERENTOR, (Latin, *circumferre*), an instrument used by surveyors in taking angles; it consists of a brass circle and index, in one piece, commonly about seven inches in diameter, an index about fourteen inches long, and an inch and a half broad. On the circle is a card, or compass, divided into 360 degrees; the meridian line of which answers to the middle of the breadth of the index. There is also soldered on the circumference a brass ring, on which screws another ring with a flat glass in it, so as to form a kind of box for the needle, suspended on a pivot in the centre of the circle. There are also two sights to screw on, and slide up and down the index, as also a ball and socket screwed on the under side of the circle, to receive the head of the tripod or stand.

CIRCUMSCRIBE, to draw a figure round another; the one being rectilinear, and the other either rectilinear or circular, with the sides of one touching all the angles of the other.

CIRCUMVALLATION, a round enclosure of trenches, or fortifications.

This word, from the Latin *vallo*, or *vallum*, denotes properly the *wall*, or rampart thrown up, but as the rampart is formed by entrenching, and the trench makes a part of the fortification, the word is applied to both.

CIRCUMVOLUTION, (from the Latin, *circumvolutus*) the act of rolling round. In architecture, this term is applied to the spirals of the Ionic capital; every term of which is called *a circumvolution*. In the most ancient examples of the Ionic order, the volute has three circumvolutions, or *revolutions*, as they are otherwise called; but that of the temple of Minerva Polias, at Priene, has four. *See* VOLUTE, SPIRAL, and IONIC ORDER.

CIRCUS, in antiquity, a large enclosed space, adapted for chariot-races, an amusement to which the Romans were passionately attached. The name Circus does not convey an exact idea of the form of this building, which both in its outline and its use resembled the Greek stadium.

There were many circi in Rome, of which the Circus Maximus, and the Circus Agonalis, were perhaps the largest. The former may still be distinctly traced; the latter retains its external form only in the Piazza Navona of Rome. This species of edifice appears to have been very early introduced among the Romans, and, like many of the first public edifices, was of a temporary character, and constructed of wood.

The first permanent circus, at Rome, was said to have been built by Tarquinius Priscus, and was situated in a valley between the Palatine and Aventine hills. On this side was afterwards erected the Circus Maximus, which was enlarged by Julius Cæsar, and rebuilt and richly ornamented by Augustus. In the time of Nero it was burnt down; Trajan repaired it, and increased its dimensions so much, as to contain the whole Roman people. The exterior of the circus, except at the *carceræ*, consisted of two stories, adorned with columns, and finished with a terrace. The ground-floor was occupied by merchants, except on the days appointed for the games. Augustus brought an obelisk from Egypt 126 feet high, and placed it in this circus. Constantine also erected in it the obelisk now called the Lateran, which is the largest of all the Roman obelisks.

The Flaminian circus was of considerable magnitude. Its only remains are ruins beneath the present pavement of the city. There are several other circi, the ruins of which may be traced; but that which demands our attention most, is the circus of Caracalla, as very considerable traces of its ancient form are yet to be seen.

Several of the circi in Rome, were exteriorly surrounded with magnificent porticos, except on the side where the carceræ were placed. Others were simply enclosed with a wall, pierced with doors and windows, as in the circus of Caracalla. The lower part of the circumference of the circus, beneath the seats, together with the porticos, formed long galleries of arcades, or *fornices;* serving in part for an access to the staircases leading to the seats, and in part for the shops of various traders. The staircases of different circi were variously distributed, according to the judgment of the architect. The principal staircases led to a number of little doors in the podium, which was a long open platform, or passage, encompassing the edifice at an elevation of some feet from the area of the circus. The persons of the imperial family, the principal magistrates, and the pontiffs, only were admitted into the podium. Behind the podium there was a little wall with a precinctum, in which small doors were distributed. The seats rose one above another, their whole height, in the manner of steps, and were supported on the inclined vault of the gallery or portico beneath them, and ascended from the podium to the top of the external wall.

The great circi, as well as the theatres and amphitheatres, were divided into several ranges of seats, for the purpose of placing the spectators according to their condition. The seats began from the wall at the back of the podium, and after setting off a sufficient number for persons of the first rank, the staircase of seats was interrupted by the omission of two or three, which formed an ambulatory, or via, similar to the podium, at every certain number of seats. Separate staircases led to each via, through doors in the precinctum; these apertures were called *vomitoria*. As the spectators entered by these passages at the top of the ranges of seats, they would have to descend to occupy the first rows of each mœniana, and since the seats themselves were too high to serve as steps, staircases, called *scalares*, formed by cutting down a seat into two steps, were provided. The scalares were placed opposite the vomitoria, beginning from the via, and descending to the lower seat of each range; by this means the ranges were divided into a number of compartments, called *cunei*, as in the theatres and amphitheatres; in the latter they obtained this name from their radial direction, and though the sides of the circus were straight, and the compartments consequently of a rectangular form, they were called cunei, from usage.

Over the seats was a portico, or covered gallery, for the accommodation of the lower class of people. The place for the emperor was called *pulvinar*, the situation of which is not known: it is supposed to have been a magnificent logia. To render the seats more comfortable, they were covered with wood.

The extremity of the circus, opposite to the semicircular end, was called *the oppidum*, and consisted of a series of thirteen arcades. The centre arch, of the same height, but wider than the rest, served as an entrance to the circus. At each extremity of the oppidum, was a tower, which surmounted every other part of the edifice. This combination of arches and towers, seen at a distance, gave the idea of a castle, whence was derived the name of oppidum. To what purpose these towers were appropriated, is not known. The twelve remaining arcades were the carceræ, whence the chariot-race began. These carceræ were placed six on each side of the entrance, which was intended for the use of the processions, and are so disposed, by the inclination of the chord-line of the segment on which they may be said to be set off, that the starting of the twelve chariots was equalized. The divisions of the arcades within, on the front, were ornamented with Hermes supporting a cornice, in the manner of Caryatides: the carceræ were closed with grated doors, to the height of the

springing of the arch, and the semicircular opening above was filled with a marble lattice. Two of these lattices, very elegantly ornamented, are at present to be found in the court of the palace Mattei, which is founded upon a part of the Flaminian Circus. The top of the carceræ formed a terrace, upon which was placed the tribune of the consul.

The spina, as being dedicated to the gods, was the most sacred place in the circus. It consisted of a platform, nearly two-thirds of the length of the circus, and, running down the middle of the arena, divided itself nearly into two equal parts, resembling the spine of a fish, whence it took its name. At the extremities of the spina were placed the metæ, or goals, which consisted of three cones placed in a triangle. On the summits of these cones was placed a large egg, in memorial of the eggs of Castor and Pollux. The metæ rested upon the vault of a semicircular temple or chapel, a little wider than the spina. The circular part of these little chapels was at the first goal, turned towards the triumphal gate, and their entrances were in passages between them and the spina. The long extent of the spina was ornamented with columns, statues, and altars. It is remarkable that the spina was not situated in the middle of the arena, nor parallel to the sides of the circus, but in an inclined direction, so that the course was wider on the right side of the circus, where it began, than on the left, and diminished gradually all the way. The reason seems to be this, that the chariots, starting all together, required more room in the first course, than when they came in separately.

In several of the circi, the arena was surrounded at the foot of the podium with a canal, called *euripus*, which was 10 feet wide, and probably of the same depth, for the defence of the spectators, in cases where the podium was not sufficiently elevated: it does not appear, however, to have been absolutely necessary, since Nero had that of the Circus Maximus covered over, in order to enlarge its area; neither is there any euripus in the circus of Caracalla.

The following description of the games exhibited in the circus may be interesting. These games, according to tradition, were instituted by Romulus, under the name of Consulia, in honour of the god Consus (Neptune). They were exhibited on various occasions, and for various purposes, sometimes by the magistrates, sometimes by private citizens. The games were opened by a grand procession from the capital to the circus, in which the images of the gods were borne in carriages, followed by dancers, musicians, combatants and others; and, last of all, by the priests, to perform the sacred rites. The exhibition consisted chiefly of chariot and horse races; the charioteers were divided into four classes, distinguished by the colours of their dresses. The order in which the chariots stood was determined by lot; and the signal for starting was given by dropping a cloth. The chariot which first ran seven times round the course, was victorious, and the driver, after being proclaimed by the herald, was crowned by a palm-wreath, and received a sum of money. Besides these races, were contests in running, leaping, boxing, wrestling, and throwing the discus. Wrestlers were anointed with ointment by slaves; boxers used gloves strengthened with lead or iron, to give force to their blows; the combatants were almost entirely naked, and all underwent a preparatory training and dieting—sometimes sea-fights (*naumachia*) were represented, and Julius Cæsar revived the exhibition of mock-fights by young noblemen on horseback.

The most attractive of these public entertainments, however, were the combats of wild beasts, either with one another, or with men. Great expense was incurred to provide the beasts for this exhibition, and they were collected for the purpose from the most remote parts of the empire The men engaged in such contests, were either forced to the combat as a punishment, or induced to enter it by sums of money. The beasts were kept in inclosures (*vivaria*) till the time appointed for the show. So passionately fond were the people of these games, that the expression *Panem et Circenses*, 'Bread and the Circensian Games,' was commonly used to signify the two prime necessaries of life to the Roman populace. The splendour of these exhibitions increased in the latter days of the republic, and the number of rare wild animals that were exhibited but to be destroyed, is almost incredible. It is said, that on one occasion, Pompey exhibited five hundred lions, which were all despatched in five days.

CISOID, or Cissoid, in geometry, a curve line of the second order, invented by Diocles, an ancient Greek geometrician, for the purpose of finding two mean proportionals between two given lines, of such property, as that if on the extremity, B, of the diameter, A B, of the circle, A O B, the indefinite perpendicular, C B D, be erected, and if from this, several lines be drawn to the other extremity, A, to cut the circle in I, O, N, and if upon these lines be set the corresponding equal distances, viz. H M = A I, F O = A O, C L = A N, &c., then the curve line drawn through all the points, M, O, L, is the cisoid. Other methods of constructing this curve may be seen in Newton's *Universal Arithmetic*, and Emerson *on Curve Lines*.

CISTERN, an artificial reservoir or receptacle for holding water, beer, or other liquor, as in domestic uses, breweries, and distilleries.

Cisterns of earth must be lined with good cement, to make them retain the water, and the bottoms should be covered with sand to keep it sweet.

Water for the use of a house, may be preserved in the cellar, where a cistern or cisterns may be constructed in the following manner: first lay a good bed of sound well-tempered clay, for a bottom, on which place a flooring of bricks, or impervious stones, cemented with plaster-of-paris, or terras-mortar. The sides should then be built up, leaving a space between them and the walls of the house, which is afterwards to be filled up with clay, well rammed down; this will keep the water from oozing, and effectually preserve the foundation of the house. As a substitute for plaster-of-paris, or terras-mortar, a composition of slacked lime sifted, linseed oil and tow or cotton, will be found very serviceable. A cistern of this kind, viz. of clay lined with bricks, will answer in any shady place, as well as in a cellar, provided it be kept covered. And though the cistern be not always full of water, the clay will not lose its requisite degree of moisture.

When a cistern is to be made above ground, it may be constructed of planks, plain or straight jointed, put together with white lead, and pinned to bearers and uprights. If the cistern be large, suppose 10 feet in altitude, and 20 feet square, the planks may be $2\frac{1}{2}$-inch yellow deals, the joists and uprights may be 4 inches thick, and 6 inches deep, placed about 2 feet 6 inches distant from each other. There should be two pins at each intersection of a board and upright, or bearer; every pin may be three-fourths of an inch thick, and wedged again with a small pin at the narrow end, to prevent the possibility of its drawing: the pins should all have a draught, to bring the joists as close as possible. This cistern, placed upon a firm well-tempered bed of clay, should be surrounded with a stone or brick wall, at 8 or 12 inches distance, and the cavity filled in with clay, as above described. This will retain the water, and answer extremely well for the supply of a city or village.

If the cistern be to be raised on high, where walls cannot be constructed around, it may be made of timber, in the foregoing manner, and lined with lead: but as this lining tends to contaminate the water, the casing of the exterior with stone or brick, with puddle between it and the wooden cistern, should be adopted when practicable.

A cistern may be constructed for watering cattle, by excavating the ground where there is a descent, and covering the bottom and sides with two coats of tough clay, each coat about six inches thick, well rammed; the bottom being covered with flag-stones, the clay will remain moist, and free from cracks, though not covered with water. But this is troublesome; for, should the clay happen to crack in any part, it would be necessary to go over the work again.

In a chalky soil, a cistern may be formed by digging a hole, and covering the bottom smoothly with chalk rubbish, which, when wetted by the rain, should be rammed well. Afterwards cattle may be turned in to tread it till quite firm, and then it will be impervious to the water.

CITADEL (from the French, *citadelle*, a diminutive of the Italian, *citta*) a small city.

Citadel, is also a small fortification, consisting of four, five, or six sides, with bastions, by which it is distinguished from a castle, and usually joined to towns, and sometimes erected on commanding eminences within them.

Citadels may be either square, rectangular, pentagonal, hexagonal, or, indeed, of any figure; but the pentagonal is most commonly adopted. The hexagonal is generally considered as too large, and requiring too great an expenditure for the advantages to be derived from it; and the quadrangular is incapable of making a sufficient defence. Citadels are also sometimes made in the form of a star fort.

The exterior sides of the citadel, when its plan is regular, are generally, each about 150 toises, or fathoms; but this extension may be varied according to circumstances.

When the citadel is erected on a hill, or eminence, within the fortifications of the place, it is well calculated to keep the inhabitants in awe, if the garrison be sufficiently provided; but it is of little use against an enemy, when once in possession of the town itself.

The citadel will require a stronger fortification than the town, to prevent its being attacked first by the enemy, who, getting possession of it, will soon become masters of the town. A citadel has, for the most part, two gates, the one for communicating with the town, and the other with the country; the gate communicating with the town, is used in case of an insurrection or sedition, or after the town has capitulated, for the garrison to retire into the citadel; the other gate, which communicates with the country, is for receiving assistance and succours when placed under extremities. The citadel generally takes up two sides of the fortification of the parts which adjoin to it, and should be so constructed that the ditch of the place may be defended as directly as possible, either by the faces of its bastions, or by ravelins, that the enemy may have no greater advantage in attacking in one place than they would have in another. It may be farther observed, that in an extensive fortified city, a citadel may be formed by uniting two adjoining bastions, by a good retrenchment, with flanking defences: the expense of making such is very trifling, compared with that of adding another fortification to the place.

CIVIC CROWN, in Roman antiquity, a garland of oak-leaves and acorns, or ground oak, given as a reward to such as had saved a citizen's life in battle.

CIVIL ARCHITECTURE, that which embraces the erection of edifices destined for civil purposes; the term is used in contradistinction to military and naval architecture.

CLAIR-OBSCURE, or Chiaro-Oscuro (from the Italian *chiaro*, light, and *oscuro*, dark) the proper distribution of light and shade in a picture, both with respect to the eye, and the effect of the whole composition. The term is also used for a design wherein only two colours are used, most usually black and white.

CLAMP, a small piece of wood, fixed to the ends of a board, to prevent it from warping, the fibres of the clamp being transverse to those of the board. The manner of clamping a board, is either by grooving the edges of the clamp, and tonguing the ends of the board into it with brads and glue, or by grooving the end of the board, and tonguing the edge of the clamp. Sometimes the end of the clamp is mitred to the side of the board, for the sake of neater workmanship. In the best clamping, the clamp is fixed to the board with a mortise and tenon.

The flaps of shutters, small doors, lids, and kitchen-tables, which consist only of boards glued together, are most frequently clamped.

Clamp, in brick-making, a pile of bricks built upon a rectangular base, for the purpose of burning them.

Clamps are built of unbaked bricks, after the manner of a kiln, with a vacuity between the breadths of the bricks, for the fire to play through; but, instead of arching, as in kilns, the flues are gathered in, by making the layers project one over another. The place for the fuel is carried up straight on both sides, till about three feet high; it is then nearly filled with wood, which is covered with a stratum of small sea-coal, or breeze, after which the flue is overspanned. The sea-coal is also strewed between every row of bricks, and the top of the clamp covered with a thick layer of it. The wood is then kindled, and the fire is thence communicated to the coals. When the fuel is exhausted, the brick-makers conclude that the bricks are sufficiently burned.

The operation of burning bricks is attended with considerable difficulty, and requires workmen of experience, to maintain an equal degree of heat throughout the mass. If the heat be too low, the bricks will be weak and crumbly, and if too strong, they will vitrify and run together. The operation is much better performed in kilns, than in clamps; as in the former, the fire can be kept up, and regulated at discretion; while in clamps, as the whole of the fuel must be put in at once, the manufacturer is tempted to use too little, and the outside bricks are consequently under-burnt. These are called *samel-bricks*, which are sold at an inferior price. *See* Brick.

Clamp Nails. *See* Nails.

CLAMPING, in joinery, the act of securing a board with clamps. *See* Clamp.

CLASP NAILS. *See* Nails.

CLASSICAL ARCHITECTURE, such as was practised by the Greeks and Romans.

CLATHRI, in Roman antiquity, bars of iron, or wood, used for securing doors and windows.

CLAY, in common language, any earth which possesses sufficient ductility to admit of being kneaded with water.

Common clays may be divided, with regard to their utility, into three classes, viz., unctuous, meagre, and calcareous.

The unctuous contains, in general, more alumine than the meagre, and the silicious ingredient is in finer grains. When burnt, it adheres strongly to the tongue, but its texture is not visibly porous. When charged with little or no oxide of iron, it burns to a very good white colour, and is very infusible; it is therefore employed in the manufacture of Staffordshire ware. When it contains oxide of iron, or pyrites, sufficient to colour it when baked, it becomes more fusible, and can only be employed in the coarser kinds of pottery.

Meagre clay does not take a polish with the nail, when dry, by rubbing it; feels gritty between the teeth; contains sand in visible grains; and, when burnt without additions, has a coarse granular texture. It is employed in the manufacture of bricks and tiles.

Calcareous clay effervesces with acids, is unctuous to the touch, and always contains iron enough to give it a red colour when baked. Being much more fusible than any of the preceding, it is only employed in brick-making; and, by a judicious burning, may be made to assume a semi-vitreous texture. Bricks thus made are very durable.

CLAYING, the operation of spreading two or three coats of clay, in order to keep water within a vessel, or to prevent its transmission to some place or apartment where it would be injurious. This operation is also called *puddling*. Claying is necessary in the construction of canals, cisterns, vaults, &c.

CLEAM, a word used in some countries, to signify *to stick*, or *glue*.

CLEAR, in building, the distance between any two bodies when no other intervenes; or between the nearest surfaces of two bodies; as, binding joists may be placed five feet *clear* of each other, or apart.

CLEAR-STORY, the upper story of a church rising clear above the adjoining parts of the edifice, and containing a range of windows, thereby affording an increase of light to the body of the building; some indeed derive the term from the French, *clair*, light, from that circumstance; while others consider the term to have been applied from this story of the building being clear of joists, rafters, or flooring: the derivation, however, implied at the commencement of this article, seems to be the most reasonable. In some cases, this story is made of great importance, pierced with windows of greater size than those below, in the body of the edifice, as at Exeter and other cathedrals, Henry VII.'s chapel, Westminster, and some of the larger churches; in others the windows are of very small dimensions, consisting merely of trefoils, quatrefoils, or small arched foliated apertures. Very small churches seldom have clear-stories, the roof being carried over the body and aisles in a single span. There is no clear-story to the choir of Bristol cathedral.

CLEAVING, the act of severing one part of a piece of wood from another, in the direction of the fibres, either by pressure, or by the percussion of a wedge-formed instrument.

CLEETA, an ancient Greek architect and sculptor, who built the palæstra, or large court, near Olympus, in which the horse and chariot races were performed at the celebrated Olympic games. It was magnificently decorated with porticos and other ornaments; and the author was so vain of his performance, that he introduced the following inscription under one of his statues:—"Cleeta, the son of Aristocles, who invented the palæstra of Olympus, did this." *See* PALÆSTRA.

CLEOPATRA'S NEEDLES, in Egyptian antiquity, two obelisks towards the eastern part of the palace of Alexandria, constructed of Thebaic stone, and covered with hieroglyphics; one has been thrown down, broken, and lies buried in the sand: the other stands on a pedestal. The dimensions of the two are pretty nearly the same; the whole height of the erect one, including the pedestal and three steps, is about seventy-nine feet. When the French examined the base of this obelisk, the accumulation of earth around it was about sixteen feet deep. These two obelisks formed the entrance to the temple or palace of Cæsar, as it is called, though probably they were moved from some of the ancient cities of Egypt by the Ptolemys.

CLINCHING, when a nail is driven to the head through a piece of wood or board, of less thickness than the length of the nail, the driving of the point of the nail backwards, flat into the wood, while a hammer is pressed against its head, is called *clinching*.

CLINKERS, bricks impregnated with a considerable quantity of nitre or saltpetre, and placed next to the fire in the clamp, or kiln, that they may be more thoroughly burnt.

CLOACÆ, large arched drains, formed under the streets of some ancient Roman cities. The most remarkable were the cloacæ of Rome, large portions of which still remain in excellent repair. These cloacæ extended under the whole city, and were divided into numerous branches: the arches, which supported the streets and buildings, were so high and broad, that a waggon loaded with hay might pass under, or vessels might sail in them. At proper distances, in the streets, there were openings, for the admission of dirty water, &c. These branches ran in the low parts between the hills, and fell into one large arched drain, constructed of solid blocks of stone, called the Cloaca Maxima, said to have been built by Tarquinius Superbus, and repaired in later times by Cato the Censor, and his colleague in office. The Cloaca Maxima is fifteen feet wide, and thirty high, with three arches in contact one within another; in some parts there were raised paths along the sides of the cloaca; and in the walls were stone brackets to support the ends of the waste pipes of the fountains. In the year 1742, a part of the Cloaca Maxima was discovered in the Forum, at the depth of thirty feet from the surface. *See* SEWER.

CLOAK-PINS AND RAIL, a piece of wood attached to a wall, furnished with projecting pegs, on which to hang hats, great-coats, &c.; the pegs are called *cloak-pins*, and the board into which they are fixed, and which is fastened to the wall, is called the *rail*.

CLOCHARIUM, CLOCHIER (French, *clocher*,) a building, more usually a tower, in which the clock and bells were contained.

CLOGHEAD, a name applied to the curious round towers of Ireland. *See* TOWER.

CLOISTER, (Latin, *clausum*, enclosed, shut in;) a covered range of building attached to a monastic or collegiate establishment, forming a passage of communication between the various buildings, more especially between the church and chapter-house. Cloisters were employed as places of meditation and recreation by the inmates of the etablishment; and sometimes of retirement and study, for which purpose we occasionally find them arranged with cells on one side, as at Gloucester Cathedral, and also at Durham, where such cells were termed carrols: they appear to have been used likewise as places of sepulture. Cloisters are invariably found contiguous to the church, ranged round three or four sides of a quadrangular area, having on the outer side a series of windows with piers and columns looking into the quadrangle, and in the inner side, which was in other respects plain, a number of doorways communicating with the surrounding buildings, the chapter-house, refectory, schools, and such like. The windows in our English cloisters are glazed, and the whole length of the ambulatories arched over with a vaulted ceiling; in some cases, a stone seat or bench is carried round the wall opposite the windows. Attached to the cloister is usually a lavatory or conduit, at which the monks washed previous to entering the refectory; the remains of one such are to be seen in the centre of the quadrangle at Durham, as also at Wells; lavatories also exist in the cloisters of Norwich, Gloucester, and Worcester. *See* LAVATORY.

In England cloisters seem to have been appended to all cathedrals, and to the majority of collegiate and monastic

establishments, in short, to all the larger religious houses. Frequent examples are also to be found on the continent, in Italy, France, and Germany, and in some cases of great magnitude; they are in the main similar to those in England, though of different styles, and therefore varying in detail; one difference consists in the windows being unglazed, on account, no doubt, of the difference of climate; in some instances are found specimens of painting in fresco on the walls.

Of the continental cloisters, Mr. Hope says, "Those of the Latin church are all of them in the Lombard style; some, such as those of San Lorenzo and Santa Sabina at Rome, and of San Stephano at Bologna, are small and rude, and more like the courts of a mean habitation; others, as those of San Giovanni Laterano at Rome, and those of San Zeno at Verona, are spacious, and formed of columns of the most fantastical shapes; some coupled, twisted, and with spiral flutes; and glittering—those at Rome with white marble inlaid with porphyry, with serpentine and with gilt enamel; and those at Verona with the gold-coloured marble of the Euganean mountains. The cloisters of the cathedral church of Zurich, and of the monastery of Subiaco, in the papal states, are amongst the most elegant of continental examples. The latter was erected in 1235, and that of San Zeno, at Verona, in 1123."

The following account of the Campo-Santo at Pisa, one of the most famous cloisters in Europe, is given by Britton:—"Its form is an oblong square, or irregular parallelogram, measuring 430 and 415 feet in its longest extent, by 136 and 139 feet at its ends. The width of each walk is about 32 feet. It was commenced in 1278 by Giovanni de Pisa, and a chapel, adjoining its east end, was completed in 1464. Between the covered walk and the enclosed area, is a series of sixty-two windows, having semi-circular arches, and adorned with varied tracery, supported by tall light columns which divide each space into four lights. Some of these were formerly glazed, but the others were left open. The floor is paved with white marble having bands of blue, and the inner roof is formed of timber. On the walls are numerous old paintings of great interest, being some of the first productions on the revival of that art at the beginning of the fourteenth century. There is also a fine collection of marble sarcophagi, fragments of sculpture, &c."

Amongst many other of the more noted cloisters of the continent, may be mentioned that belonging to the monastery of Batalha in Portugal. It is extensive and highly enriched, the length of each ambulatory being 182 feet, and the width $17\frac{1}{2}$ feet; in the centre of the enclosed quadrangle is a cistern, and in one of its angles a large fountain.

Attached to the collegiate chapel of St. Stephen, Westminster, are the remains of one of the most highly enriched and beautiful cloisters in England, which was erected by Dean Chambers in the time of King Henry the Eighth. It is the only example remaining of a cloister of two stories; it has two oratories, or chantry-chapels, projecting into the quadrangle, and approached respectively from the upper and lower western avenues. The roof is vaulted, covered with fan-tracery, and adorned with finely-sculptured bosses and shields. The dimensions are added to the following table.

The areas at the entrance of some continental churches partake of the nature of cloisters, but are more particularly styled atria. *See* ECCLESIASTICAL ARCHITECTURE.

The annexed is a table giving the dimensions and some other information relative to the cloisters attached to our English cathedrals. The particulars are collected from Britton's works, and other similar sources.

List of Cloisters of the English Cathedrals.

	Length.	Width of avenue.	Height to vaulting
	Feet.	Feet.	Feet.
[a] CANTERBURY	132		
CHESTER	110 108		
CHICHESTER	198 S. 121 E.		
[b] DURHAM	145	15	
[c] GLOUCESTER	147	frm 12 to 14	17
[d] HEREFORD	143 115		
[e] LINCOLN	118 N. and S. 90 E. and W.	13	
[f] NORWICH	from 175 to 177	$14\frac{3}{4}$	15
[g] SALISBURY	$181\frac{3}{4}$	18	$20\frac{3}{4}$
[h] WELLS	162 E. and W. 158 S.	13	
[i] WORCESTER	125 E. 120 W.N. & S.	16	17
[k] OLD ST. PAUL, LONDON	91	10	
S. STEPHEN'S CHAPEL, WESTMINSTER	89 E. and W. 75 N. and S.	$12\frac{1}{2}$	14 lower 13 upper

REMARKS.

[a] On north side of cathedral.

[b] Date about 1400; had octagonal lavatory in centre of area. On south side of cathedral.

[c] Completed 1390; has recesses or carols in the south walk, and in the north a spacious lavatory; the roof covered with elaborate fan-tracery.

[d] In ruins.

[e] Has timber vaulting with ribs and bosses; on north side of cathedral; date about 1300.

[f] Commenced in 1299, completed in 1430; has two lavatories at the south-west angle.

[g] Date about 1250; situate on south side of cathedral.

[h] Erected between 1407 and 1465; on the south side of cathedral. It has only three avenues, the fourth side being the wall of the nave; the eastern and western sides are of two stories; there is a lavatory in the area.

[i] Date 1380.

[k] Consisted of two stories; the chapter-house was enclosed within the avenues. Destroyed.

CLOISTER-GARTH, the quadrangular area enclosed within the four avenues of a cloister; it was laid out as a grass-plot, and had frequently in its centre a stone conduit, or reservoir of water.—The cloister-garth was used as a place of sepulture.

CLOSE STRING, in dog-leg stairs, a staircase without an open newel.

CLOSER, in masonry, the last stone laid in the horizontal length of a wall, of less dimensions than any of the others in the same row. Closers should never be admitted in good work, nor indeed in any other, for they deprive it of uniformity, and destroy the bond also: nor would they ever be found necessary, were due attention paid to the dividing of the stones in proper lengths. In brickwork the term is applied to a bat used in the same manner. When the bat is a quarter-brick, it is called *queen-closer*. When a three-quarter, inserted at the angle of a stretching-course, it is called a *king-closer*.

CLOSET, a small apartment, frequently made to communicate with a bed-chamber, and used as a dressing-room. Sometimes a closet is made for the reception of stores, and then it is called a *store-closet*. However unfashionable closets may be in the rooms of large houses, they are essential in those of small ones.

CLOSET. *See* WATER-CLOSET.

CLOUGH, or Cloyse, a kind of sluice for letting off water gently, employed in the agricultural operation of improving soils by flooding the land with muddy water, the same with *paddle*, *shuttle*, *sluice*, *pen-stock*, &c., a contrivance for retaining or letting out the water of a canal, pond, &c.

Clough Arches, or Paddle-Holes, in the construction of canals, crooked arches by which the water is conveyed, on drawing up the cloughs or paddles, from the upper pond into the chamber of the lock, when it is to be filled.

CLOUT-NAILS. *See* Nails.

CLUB-CHAMBERS. As the building we are about to describe is the first attempt to provide a superior kind of accommodation for gentlemen who are accustomed to reside in chambers, by the erection of an edifice especially planned for, and adapted to the purpose; we think a notice of the extensive and elegant institution known as the Club-chambers in Regent Street, not inappropriate in a work devoted to architecture.

In consequence of the scarcity of chambers for residence in the vicinity of the Clubs and Houses of Parliament, an association was formed for the purpose of supplying the want. An eligible site having been procured in Regent Street, between Pall Mall and Piccadilly, the association engaged Mr. Decimus Burton to make designs for a new building. These designs being approved of, contracts were made, and the result was the present handsome and commodious mansion.

The elevation of this edifice is of the Italian style of architecture; it occupies a frontage of 76 feet, and consists of a ground-story, rusticated, and terminated by an enriched lace-band or string-course, enriched with the Vitruvian scroll. This story forms a basement to the upper part, containing the principal story, and a second and third story, surmounted by a bold and enriched cornice, the main characteristic feature of the Italian style. Between the principal story and the ground-floor, an entre-sol is introduced, the windows of which are placed between the panelled pilasters supporting the consoles of the bold projecting balconies in the windows above. The ground-floor is approached in the centre by a portico, projecting forward with coupled Doric columns on each side, and recessed back to give depth: this opens into a grand entrance-hall, the height of the ground-story, and entre-sol. The four upper stories are divided in the same way as the ground-floor, except that on all the stories above the entre-sol there is an apartment over the entrance-hall.

The building contains 77 chambers; 27 are provided with alcoves or recesses for the bed, and 50 without; some of the rooms are so planned, that two or three may be formed into one suite, if required. The basement-story—occupied as servants' rooms and domestic offices—is arched over with flat brick arches, supported by iron girders. The two staircases are of stone, all the corridors have stone floors, and every precaution has been taken throughout the building against the extension of fire.

The ingenuity displayed by the architect in providing for the warming and ventilation of the building deserves a particular description—it is thus effected:—On each side of the principal staircase, on the basement-story, is a furnace, with an iron pipe or flue 12 inches diameter, fixed in the centre of a vertical brick-chamber, rising through the several stories and roof, where it is terminated by a cowl. On each story these vertical chambers communicate with horizontal ones, formed between the floor and ceiling of the corridors. Each room being furnished with a ventilator near the ceiling, opening into the horizontal chamber; when the fire is lighted in the furnaces, it heats the iron flue, rarefies the air within the vertical chambers, and causes it to pass off with considerable rapidity through the cowl at the top. The air within the rooms then flowing through the ventilators and horizontal chambers into the vertical ones, supplies the partial vacuum created by the escape of the rarefied air, and thereby keeps up continuous and healthy circulation.

The warming of the building is effected by the patent hot-water apparatus of Mr. H. C. Price, erected under the superintendence of Mr. Manby. The apparatus is erected on the basement-story, on the north side of the principal staircase; the hot-air chamber is immediately behind, the top being nearly on a level with the ground-floor; a supply of cold air flows through a trunk—the mouth of which is furnished with gauze-wire to filter the air—into the vault, where it passes upwards between the vertical iron chambers filled with hot-water, and becomes heated, the warm air then escaping through apertures in the top of the vault, is distributed throughout the principal staircase and corridors. The corridors and water-closets are lighted with gas, the light being enclosed in glazed lanterns, provided with tubes leading to the external part of the building. On the basement-story, a well has been sunk, by which the premises are supplied with pure spring water lifted to the top of the building by means of a small steam-engine, which is also employed for raising coals, furniture, &c., up the well-hole of the back staircase. Every alcove or recess for the bed is provided with hot and cold water, and pipes trapped, and communicating with the drains for a water-closet, if the tenant should wish to have one.

We have been thus particular in describing this establishment, because the very perfect arrangements made in it for the comfort and convenience of its numerous occupants reflect the highest credit on the architect, whose taste and ingenuity have been so eminently displayed; and because we would bespeak for so valuable an association the patronage and support its liberality so fully deserves.

CLUB-HOUSE. Under this term are designated the splendid establishments which have sprung up at the west-end of the metropolis within the last few years. Called into existence by the requirements of a highly refined state of society, the clubs of London represent an assemblage of gentlemen composed of all that is eminent in rank, wealth, and talent; the *elite* of the gentry and nobility of the kingdom.

The clubs of the present day must not be confounded with those of a past age, they are essentially institutions of modern creation. Of the clubs of former days, the earliest described in our popular literature date about the end of the sixteenth, or the beginning of the seventeenth century. About that time was established the famous club at the Mermaid Tavern in Friday Street, amongst whose members were Shakspere, Beaumont, Fletcher, Raleigh, Selden, Donne, and others.

Another celebrated club, founded by Jonson, held its meetings at the well-known Devil Tavern. For this club Jonson wrote the "Leges Convivales," which are printed among his works. In the Spectator, Addison describes an association of a political character, called "The Club," or rather the Confederacy of the Kings. "This grand alliance," says he, "was formed a little after the return of Charles II., and admitted into it men of all qualities and professions, provided they agreed in this surname of king, which, as they imagined, sufficiently declared the owners of it to be altogether untainted by republican and anti-monarchical principles."

The great age of clubs, political, literary, and of every other description, was the early part of the last century. Amongst the most celebrated of these was the *first* Beef-steak club, of which Mrs. Woffington, the popular actress, was the president, being the only female member; and

Estcourt, the comedian, *provisor*, wearing in that character a small gridiron of gold hung round his neck with a green silk riband. Still more celebrated, perhaps, was the famous Kit-Cat club, said to have been instituted at the time of the trial of the seven bishops in the reign of James II., but in its greatest glory in that of Queen Anne.

In 1735 was established the *second* Beef-steak club, which is still in existence, and which has numbered among its members the most eminent public characters that have appeared since its institution. This club originated with Rich, the pantomimist, and the Earl of Peterborough, and has continued to the present day to maintain its high celebrity, as the chosen resort of good-fellowship and conviviality.

The modern clubs are associations of gentlemen of similarity of political feeling, literary or professional pursuits—as the Reform, the Carlton, Athenæum, United Service, &c. These are, in no other respects, clubs, according to the ancient English understanding of the term, except that every member must be balloted for, or admitted by the consent of the rest. They might perhaps be more correctly described houses as combining the characters of restaurants and reading-rooms, for the use of a selected number of associated persons, who agree to make an annual payment for their support, whether they resort to them little or much; and pay besides for whatever refreshment they may require, at a cost free of profit. Originating within the present century, and concentrating a large proportion of the men of fortune, station, and political note in the metropolis, these establishments have certainly had a striking effect upon the manners, not only of the departments of society from which the members are drawn, but upon society in general. They have, indeed, given a new direction to the habits of certain classes, and the change has been decidedly for the better.

Although it is our province more especially to describe the buildings in which these institutions are domiciled than the institutions themselves, a slight account of the origin and progress of the latter, abbreviated from an interesting sketch in Chambers' Edinburgh Journal, may not be uninteresting.

It appears that to the military we are indebted for the origin of these establishments. The officers of the army, whether in camp or quarters, have always experienced the advantage and economy of *clubbing* for their provisions. They have found that the pay of each individual, spent separately, would scarcely procure him ordinary necessaries; whilst, by adding it to a general fund, to be judiciously disbursed by an experienced caterer, he would obtain for his subscription not only requisites, but luxuries.

At the peace of 1815, a reduction of the army withdrew a number of officers from the "*messes*" to which they had been accustomed. Thus a great many gentlemen of comparatively limited means were thrown into private life, subjected to all the expenses and inconveniences of hotels, taverns, and lodging-houses. In many instances long and continued absence from home had severed these brave men from domestic ties; yet having always lived among a congenial brotherhood-society, it was essential to their happiness. In these circumstances, the *mess-system* was naturally thought of, and the late General Lord Lynedoch, with five brother-officers, met for the purpose of devising a plan by which a similar system might be made applicable to non-professional life. So effectual were their deliberations, and so well-grounded their preliminary measures, that a club was formed during the same year, (1815,) intended, in the first instance, for military men only, but naval officers, as well as military, were afterwards brought within the scope of their design, and an association enrolled, entitled the "United Service Club."

A building fund was formed; a neat edifice,—from the designs of Sir Robert Smirke,—was erected at the corner of Charles Street, St. James's, and in the year 1819 the first modern club was opened for the reception of its members. Candidates for admission, however, increased so rapidly, that a larger habitation was rendered necessary. A building, on a grand scale, from the plans of Mr. Nash, was erected at the east corner of the new entrance to St. James's Park from Pall Mall, and taken possession of in 1828, while the residence in Charles Street, vacated by the "United Service Club"—now generally called the "Senior United Service"—was taken by a new association, under the title of the "Junior United Service Club."

The establishment of the "United Service Club" was speedily followed by that of others, and the number of these institutions, which is daily increasing, now amounts to above thirty. The principal club-houses are situated in Pall Mall and its immediate neighbourhood, and a person re-visiting London, after an absence of several years, would be surprised to see here clustered together a number of mansions exhibiting every order of architecture, from the severest Doric to the most florid Composite. The following description, subject, of course, to modification in particular instances, will give a tolerably correct idea of the *general* arrangement of a modern club-house.

The visitor, on entering one of these palace-like edifices, finds himself in a lobby, in which are the hall-porter, who is seated at a desk, and his assistants. The duty of these officials is to see that none have access to the club but members, to receive letters, &c. Close to the hall is a reception-room for strangers wishing to see members, and beyond this a hall, or vestibule, from which doors open on the various apartments on the ground-floor. Of these there is, first, a "morning room," which is used for reading newspapers and writing letters. And to give some idea of the liberal scale on which these morning-rooms are supplied, and of the profusion of periodicals taken in by the large clubs, it may be stated that at the Athenæum, in the year 1844, the sum of £471 2s. 6d. was expended for English and foreign newspapers and periodicals. Stationery also is supplied to an unlimited extent.

The "coffee-room" is furnished with rows of small tables projecting from each side, with an avenue up the middle. These tables are laid for breakfasts and luncheons till four o'clock in the day, after that hour they are arranged for dinners. For the accommodation of members who may feel inclined to form themselves into parties to dine together, in preference to the *detached* mode of dining at the small tables of the coffee-room, a dining-room, handsomely furnished, is provided on the ground-floor, in which they can do so—these dinners are termed, in club-parlance, "house-dinners."

The principal apartment above stairs is the drawing-room, in which members take their evening coffee or tea. In some clubs a great display of luxury and expensiveness is made in this room, and, notwithstanding that it is perhaps less used than any room in the house, the finest taste of the decorator and upholsterer is called into requisition to adorn it. Near to the drawing-room is the library, fitted up with every convenience for reading, consulting maps, &c. The books are accumulated by donations, and by a sum set aside from the general funds for their purchase. These libraries are generally well supplied with books, and that of the Athenæum is said to contain near 30,000 volumes. Five hundred pounds is annually expended by this club for increasing its library. Near the library is, in some clubs, a card-room, but gaming is as much as possible discouraged in these institutions.

The next story contains at least one billiard-room, some club-houses have two; in many clubs also there is a smoking-room: on the upper story are sleeping chambers for the servants, who reside on the premises. The basement contains the usual domestic offices; and, as may be supposed, every detail connected with the important department of the "*cuisine*" is most perfect.

The above sketch will give the reader some idea of the general arrangements of a club-house; we shall now proceed to describe more particularly a few of those splendid edifices which have been, by some, compared to the *Palazzi* of Italian cities.

The "United Service," though first in seniority as a club, deserves a very brief notice on the score of architectural beauty. It is a plain unpretending building, which may be called Italian, because it cannot be described as being of any other style, but it is Italian of an impoverished and enfeebled character, exhibiting, remarks Mr. Leeds, "incontestable evidence of insipidity and poverty."

The building consists of two stories, the ground-floor being rusticated, and having windows on each side of the portico. The upper story contains an elegant *suite* of rooms, having seven lofty windows, with pediments, over which, and running through the whole building, is an entablature, the whole being surmounted by a balustrade. The south front is similar to the one described, but the north, facing Pall Mall, has a portico the whole height of the structure, and is in two divisions; that of the ground-floor being composed of eight fluted Doric columns in pairs, having an entablature with triglyphs. This is surmounted by a balustrade, over which are eight Corinthian columns arranged in the same order as those below, and crowned by an entablature and pediment. The internal arrangements are exceedingly well contrived, and furnish every convenience for the accommodation of the members. There are some remarkably fine portraits of distinguished military and naval officers, and the apartments are furnished with great luxury and elegance.

The "Athenæum," is situated at the opposite angle of Carlton Place, and is remarkable for the elaborate sculptured bas-relief frieze continued along its three sides. This club ranks as one of the very first in the metropolis, and the magnificent mansion belonging to its members, is worthy to occupy a similar prominent position.

The building is from the designs of Mr. Decimus Burton, and displays that gentleman's usual ability and good taste. The east elevation has a rusticated basement with a portico, the ends of which are filled up and perforated with windows; the angles are finished by a square pilaster and fluted column of the Doric order; the space between being divided by four columns of the same order in pairs. The frieze is ornamented with triglyphs, and the cornice surrounded by a balustrade, the space over the centre intercolumniations being filled up and crowned by a pedestal supporting a figure of Minerva.

Over the ground-story, and on a line with the cornice of the portico, is a balcony running through the three elevations, and terminating at the angles by pedestals. The principal story is lighted by seven lofty windows with sashes, by which there is access to the balcony, and which are ornamented with cornice and trusses; above this, and continuing through the entire building, is the beautiful frieze we have already mentioned, the figures, in basso-relievo, being copied, it is said, from the Elgin frieze deposited in the British Museum. Over this is a cornice of very bold projection, the whole being crowned by a balustrade.

Adjoining the Athenæum, is the "Travellers'," of which it is scarcely possible to speak in terms of sufficient commendation. "Could there," says a talented writer and able critic, "be any question as to the possibility of reconciling the seemingly antithetical qualities of richness and simplicity, this building might be allowed to determine it, since the design is no less remarkahle for the attention bestowed upon all its details, than for the simplicity of its composition." We have many others far more ambitious in decoration, yet not one so beautifully finished up in every part, or exhibiting so perfectly that *integrity of finish* which is displayed in this work of Mr. Barry's. For here, indeed, we behold the full beauty of the Italian style purified from its defects, and stamped by a serene kind of dignity that renders it truly captivating.

In the treatment of his design, Mr. Barry has bestowed equal pains on both fronts, that towards the garden being as carefully studied as the one facing Pall Mall; and it is well worthy not only of observation, but of imitation, that there is more nicety of detail and greater elegance here bestowed on parts sometimes considered of very secondary importance, than is often expended upon a whole design. If, again, we lift our eyes to the upper extremity of the building, we instantly perceive what attention has been bestowed on that also; for it is not the cornice alone, but the cornice and roof together which constitute its decoration; the latter being treated as belonging to the elevation itself, and the former giving richness and majesty to the whole façade.

The interior of the building is arranged with great ability, both with regard to convenience and picturesque effect, for which latter it is not a little indebted to a small but elegant internal court, of strictly architectural character.

The position of the entrance, which a regard to exact symmetry would have required to be in the centre, has been sometimes objected to, but we are of opinion that the architect exercised a sound judgment in placing it where he has, rather than sacrifice a portion of the interior accommodation.

The following description of this elegant structure, is extracted from an excellent work, "The Public Buildings of London," edited by Mr. W. H. Leeds:—"The hall, which has a screen of two columns in antis,—behind which is the porter's desk,—includes the window next to the entrance-door. Although small in itself, it does not by any means look confined, there being a vista from it along the corridor, which is lighted by three windows looking into the court, and to which there is an ascent of four steps through an open arch. The ceiling of both hall and corridor are arched; that of the former coffered, of the other panelled. A door to the left, immediately after ascending the steps, leads into the morning-room, (44 feet by 23 feet 9,) which has three windows towards the street, and a fire-place at each end. From this, a door facing the farthest window, opens into the house dining-room, which is 27 feet by 28 feet 9 inches, and occupies all the space to the east of the court. Beyond the principal staircase, which is seen at the end of the corridor through an open arch, is the coffee-room, occupying the whole extent of the garden front. This room is divided by piers and antæ into three compartments, in each of which is a fire-place, namely, one at each end, and another facing the windows in the centre division.

"The libraries form a single apartment, divided by double screens of Corinthian columns on a pedestal stylobate in continuation of the dado of the room, leaving a passage through the centre intercolumn six feet clear. Owing to the contraction of the opening, to the depth of the screen, and the duplication of the columns one behind another, the perspective appearance acquires a high degree of pleasing complexity, and the larger or inner library is not so much exposed to view, on first entering from the staircase. Above

the entablature is a deep frieze, forming a continued subject in bas-relief. Over the libraries are billiard and smoking-rooms, which are lighted from above in the slope of the roof towards the court."

The drawing-room and card-room are loftier than the libraries, and have a deep cove with coffers between the ceiling and the top of the cornice. The design of the drawing-room ceiling is exceedingly tasteful, combining finished simplicity with richness in a very striking manner, and all the details exhibit proofs of the most refined taste and the most careful and elaborate design.

The dimensions of some of the principal apartments are as follows:—

	Ft. In.	Ft. In.	Ft. In.
Coffee-room	68	by 24 9	and 18 6 high.
Principal Staircase...	45	by 16	
Corridor	27	by 11	
Court	27	by 25 6	
Drawing-room	39	by 23 9	and 24 0 high.
Card-room	28 9	by 23 9	
Libraries	48	by 24 9	and 17 6 high.
Reading-room	29 9	by 19 6	

We cannot close our notice of this elegant building, without again expressing our admiration of so great an ornament to our metropolitan architecture. The Travellers' club-house will bear the most critical and scrutinizing examination; and the more closely it is scanned, the more apparent will be its beauty; nor is it till then that we perceive how carefully every part is elaborated, and yet so subdued to the general effect, that the eye never rests on particular points thrust obtrusively forward, but embraces the perfect ensemble, in a structure replete with chaste and refined simplicity.

Immediately adjoining the Travellers' is another magnificent example of architectural genius—the "Reform Club." The instructions issued to the competing architects, by the spirited members of this association, when seeking a design for their new dwelling, were—to produce a club-house which should surpass all others in size and magnificence; one which should combine all the attractions of other clubs, baths, billiard-rooms, smoking-rooms, with the ordinary features, besides the additional novelty of private chambers or dormitories. The manner in which Mr. Barry responded to these instructions, may be seen in the edifice we are about to describe; an edifice on which public opinion and professional criticism have united to bestow the highest praise; pronouncing it unsurpassed in grandeur of design, and perfection of taste, by any building in the metropolis. The distinguishing characteristic of the Reform Club, is its grand and imposing appearance; produced, not only by its greater extent and loftiness, but by the circumstance of its being detached from other buildings on three of its sides. These are made to constitute as many façades, two of which may be beheld together from the same point of view, producing, from their uniformity in design, a continuous, rich architectural mass; and thus securing a completeness and fullness of effect which a mere façade on the same scale could never give.

In the Reform, as in the Travellers', Mr. Barry has avoided the too common fault of cutting up a composition into distinct divisions, finishing, and then commencing again; on the contrary, the ensemble is made consistent throughout, crowned by a magnificent cornicione, proportioned not to a part, but to the whole; while sufficient decoration, in other respects, is derived from essential features and members, windows, string-courses, &c. These display themselves with a boldness and effect hardly attainable where windows are introduced between straggling columns, and other like incongruities offend the judicious observer. In this building richness combined with simplicity is diffused throughout, and the eye dwells with unmixed satisfaction and delight on the harmonious result.

The entrance to the club-house from Pall Mall, is several steps above the ground, and in the centre of the building. On this side, the frontage presents only three floors from the ground, though consisting of six from the basement; the basement and mezzanine below ground, and the chambers in the roof being unseen. There are four windows on each side of the entrance; nine windows equidistant on the first floor, and the same number on the second. The pediments surmounting the windows in Pall Mall, are supported by Ionic pilasters; and at the back, overlooking Carlton Gardens, by Ionic pilasters rusticated. The height of the ground and first floor is on the same level as the Travellers'.

An Italian court ($34\frac{1}{2}$ feet by 29 feet,) is placed in the centre of the quadrangle. Corridors, on the first and ground floors, 9 feet wide, lighted from this court, lead to the apartments on these floors; but on the second floor, the corridors leading to the lodgings are contracted to $5\frac{1}{2}$ feet. On the basement, every sort of culinary office seems provided, and located with singular judgment and convenience. The number of apartments here exceeds thirty. In the mezzanine or entresol, are the butler's, housekeeper's, and still-rooms, dressing and bath rooms, and 16 servants' rooms. On the ground floor is the coffee-room, of noble proportions, having a view into the gardens; writing-room, newspaper or reading-room, house dining-room, steward's, waiting, porter's, and two audience-rooms—in all nine rooms on this floor.

On the first floor, above the coffee-room, is the drawing-room, supported by Corinthian pillars, and so constructed, that if required, it may be divided into two or three rooms; two libraries, both supported by Corinthian pillars; two billiard-rooms; and several other rooms.

On the second floor are twenty-six chambers or lodgings, the dimensions of each varying from 22 feet by 14 feet, to 12 feet by 10 feet.

On the attic floor there are about thirty rooms, intended for servants. The following are the dimensions of some of the principal apartments:—

		Ft.	Ft.	Ft.	Ft.
Basement....	Kitchen	29	by 22		
"	Steward's room......	26	by $18\frac{1}{2}$		
"	Butler's pantry	$16\frac{1}{2}$	by 14		
"	Scullery	20	by 14		
"	Cook's room.........	17	by 12		
Ground Floor	Coffee-room	117	by 28		
"	Writing-room........	40	by 27		
"	Reading-room	$28\frac{1}{2}$	by 27		
"	House dining-room ...	29	by 18		
First Floor ..	Drawing-room	117	by 28		
"	Libraries............	40	by 27	and $28\frac{1}{2}$	by 27
"	Billiard-room	32	by 18	and 23	by $17\frac{1}{2}$
"	Committee-room	$33\frac{1}{2}$	by $17\frac{1}{2}$		

In the whole building, there are upwards of 130 several apartments, arranged with the greatest ingenuity, and with the utmost attention to convenience, and showing that, however great may be our admiration of the beautiful exterior, the interior is not less deserving of our approval and commendation.

The "Carlton" adjoins the Reform, and adds another to the fine structures we have been describing. The committee of this club, after examining a number of designs submitted in competition by various architects, none of which seem to have met with approval, agreed to elect an architect by the votes of the members. The ballot resulted in the election of Mr. Sydney Smirke and Mr. G. Basevi, who had arranged to act conjointly; but the death of the latter gentleman preventing this being carried into effect, Mr. Smirke was retained by the committee to complete the work.

The general design of the building is adopted from that of the library of St. Mark, at Venice. The extent of the frontage in Pall Mall, is 133 feet, and the height is about 70 feet. The fronts are of Caen stone; the shafts of all the pillars and pilasters, of polished Aberdeen granite; and the contrast made by the red tint of the latter, has a novel and pleasing effect. The decorations of the interior, furniture, &c., are of the most tasteful and splendid description, and the coffee-room, 90 feet by 36 feet, is an exceedingly handsome apartment. The whole building presents an imposing elevation, designed with judgment and good taste. The rooms are of good proportion, and arranged with every attention to comfort and convenience; and the important details of domestic and culinary matters, as cellars, kitchens, larders, and servants' rooms, have not been neglected.

The splendid building belonging to the "Oxford and Cambridge University Club," erected from the designs of Sir Robert and Mr. Sydney Smirk, adjoins the Carlton. The front of the University club-house extends 87 feet in width, and the height from the ground line to the top is 57 feet. An entablature, marking the separation of the ground story from the principal floor, and projecting forward in the centre of the building over four Corinthian columns, divides the front horizontally into two equal parts. The centre space on the ground floor is occupied by the portico, which projects to the front line of the area; the entrance to the hall being formed by the centre intercolumniation, which is wider than the rest; the four columns stand upon pedestals, four feet high, with base mouldings and cornice. The upper part of the building is terminated with a delicate Corinthian entablature and balustrade, breaking forward with the centre of the building, which corresponds in width with the portico: the front being thus vertically divided into three compartments, the side ones assuming the appearance of wings, while the effect of a centre, indicated by the projecting portico on the ground-floor, is maintained throughout the whole height of the building. The angles of the centre division, on the principal story, are formed of rusticated pilasters; the principal window occupying the space between these pilasters. Similar rusticated pilasters also divide each wing on the principal floor into three equal oblong recessed spaces, containing windows similar to the window above described. A balcony, projecting 3 feet, continues throughout the whole line of front, the parapet being formed of pedestals with intervening panels of richly designed foliage, cast in metal in high relief, and the landing supported by elaborately enriched consoles. The frieze of the entablature over the ground-story is filled with convex panels, enriched with laurel leaves, and over each column of the portico are shields bearing the arms of the Universities. The whole of the ornamental detail throughout, is designed to correspond in richness of effect with the Corinthian capitals of the columns, which have their central volutes entwined. Below the ground-story are mezzanine and basement stories.

In the panels above the windows of the principal floor, are bas-reliefs illustrating those exalted labours of the mind, which it is the peculiar province of the Universities to foster. We have not space to describe these beautiful ornaments more minutely, but they are well worthy a careful examination, and reflect credit on the taste of the architects, and on the liberality of their employers. The arrangements of the interior are planned with great judgment, and afford every accommodation to the members of the club; but as a great similarity must necessarily exist in all establishments devoted to similar purposes, it is unnecessary to describe them.

On the opposite side of Pall Mall, is the new building erected for the "Army and Navy Club," an engraving of which, with a plan of the ground-floor, is here given. The architects are Messrs. Parnell and Smith. The following description, principally taken from that very useful publication, "The Builder," gives a good idea of the structure:—

"Although the design is based on the Cornaro palace on the grand canal at Venice, it differs materially from that building. The palace has three stories above the basement, Doric, Ionic, and Corinthian, and shows the roof, terminating on the modillion cornice of the upper order, as at the Reform club; the frieze being devoid of sculpture, and having oval openings to light an attic story. In the club-house, the general arrangement of the ground and first floor elevation of the palazzo has been adopted, but coupled Corinthian columns have been substituted for the Ionic of the latter, and the building terminates with the entablature of the order, highly enriched with sculpture and a balustrade.

"The entrance to the building is from George-street, by a flight of steps leading to a recessed portico. On the left of the entrance-hall, is a morning-room corresponding to a coffee-room on the opposite side; there is also a reception-room. The coffee-room is lighted from each end, and an elliptical dome in the centre: the dome has an exterior covering of glass, between which it is proposed to light the room at night by a gas device encircling the whole circumference. By this arrangement, the necessity for any gas-burners will be avoided, and a hot-air chamber provided, which, by the aid of flues, will afford a system of ventilation. Between this room and the strangers' coffee-room, lighted and ventilated in the same manner, and communicating with each, is placed the serving-room, connected with the kitchen by a lift, and the butler's serving-room: from this last is a direct communication to the dispensing cellars, while the room will be fitted up with ice-bins, hot and cold water, and presses for the reception of glass: there is also a separate entrance from the still-room. At the extremity of the building is placed the house dining-room, which has a separate communication with the kitchen.

"The mezzanine floor is appropriated to the members' bath and dressing rooms, and the housekeeper's department. The first floor is approached by a flight of steps, one branch of which leads to the secretary's room, and upper floor, the latter containing billiard, card, and smoking rooms—the other to the evening-room, library, and writing-room. The evening or drawing-room, is 76 feet by 28 feet; the library, 40 feet by 32 feet; writing-room, 33 feet by 18 feet. There are besides the rooms we have mentioned, a great number of others of the usual description in similar establishments."

It would be impossible, without occupying more space than can be allotted to this article, already extended beyond its due limits, to describe in detail the several handsome mansions in which other clubs, under various designations, have located themselves. The "University" in Suffolk-place—the "Union," one of the oldest and most select of London clubs—the "Conservative," lately erected in S. James's-street, on the site of the well-known Thatched House Tavern, and a host of others, are all deserving the study of the architectural student. In some, beauties of the highest order command his attention; in others, defects, he should mark, in order to avoid; in all, much may be learnt as to arrangement of apartments, and those details of convenience on which so much of the comfort and economy of a large establishment depends.

In conclusion, we would observe only, that whatever may be the faults of some of these buildings, the formation of the present club system has been the means of adorning the west end of London with a number of splendid houses, designed by eminent architects, decorated by artists of repu

tation and taste; and completed at an expenditure of the most liberal and extensive character. Nor has this been confined to London alone, the example has been followed in the country; and in many of the provincial cities and towns, clubs have been formed, and club-houses built on a scale of magnitude and splendour rivalling those in the metropolis. It is scarcely within our province, to remark on the effect the rapid extension of clubs may have on the usages of society in general; but we may be permitted to say that any system which tends to the adornment of our cities with magnificent structures decorated in the most expensive manner, and filled with costly furniture, and luxurious productions in every department of art, cannot but have a refining influence on the taste of the rising generation, while affording employment to professional talent, and to hundreds of skilful artisans.

CLUMP, in ornamental gardening, a detached portion of ground, raised in the form of a mound, in lawns or other parts of pleasure-grounds, for the reception of trees or shrubs on the top, while its sides are covered with flowers or small plants. Clumps differ from borders, in being detached and separate, as well as in being much more elevated.

CLUSELLA (Latin, *clusum*, enclosed,) a small castle within a close or inclosure.

CLUSTERED, in architecture, denotes the coalition of two or more members, so as to penetrate each other.

Clustered Column, in the pointed style of architecture, a column composed of a number of slender pillars attached to each other, but having each a distinct base and capital. Clustered columns were frequently divided in their height by moulded bands, which gave them the appearance of being bound together. They are sometimes attached to the shaft throughout their length, and sometimes only at the capitals and bases.

Clustered Column, in the Roman style, is said of two, or four columns, which seem to intersect or penetrate each other, either at the angle of a building or apartment, that they may answer each return; or under an entablature, when a single column would be too weak; or at the intersection of two transverse architraves: in the latter case, there may be four columns.

COATING, in a general sense, denotes the covering of a body in one or several plies or thicknesses; thus, walls are spread over with one, two, or three separate coats of plaster; the interior apartments of houses are covered with several coats of paint; works in wood are covered with paint, pitch, lead, copper, &c.; baser metals are covered with the richer, as copper with gold or silver, and silver with gold; for culinary purposes, copper is covered with tin, as is iron also, to prevent rust.

COB-WALL, a wall built of straw, lime, and earth.

COCHLEARE, or Cogla, a lofty round tower, ascended by means of a winding staircase; from the Latin, *cochlea*, winding stairs.

COCKING, a method of securing beams to wall-plates, by notching each beam at the end on the under edge, across its thickness, nearly opposite to the inner edge of the wall-plate, and cutting two reverse notches out of the top of the wall-plate, leaving the part whole which is opposite to the notch in the beam; then laying the beam to its place, it will slide down, and the corresponding parts will fit into each other. This method prevents any possibility of the beam drawing longitudinally out of the wall-plate, even though the timbers should afterwards shrink.

COCKLE-STAIRS, a winding staircase. *See* Stairs.

CŒMETERIUM. *See* Cemetery.

COFFER, a recessed panel, of a square or polygonal figure, anciently used in level soffits, and in the intradoses of cylindrical vaults.

In the remains of Grecian and Roman architecture, the coffers sometimes recede in one degree, but more frequently in several degrees, like inverted steps, around the panel, each internal angle being filled with one or more mouldings. In Roman works, the surface of the panel at the bottom is mostly covered with a rosette. Sometimes the bands between the framing are divided into two equal parts, by a groove or canal of a rectangular section.

Coffers are also employed in the soffits of the cornices of the Corinthian and Roman orders, between the modillions. For the farther use of coffers, and other matters relating to them, *see* Ceilings and Cylindrical Vaults.

Coffer, in inland navigation, a large wooden vessel, open at the top, with movable ends, of sufficient capacity to receive a barge or vessel from the pond of a canal, in order to be raised into a higher, or let down into a lower pond. This coffer is a substitute for a lock.

COFFER-DAM, a hollow dam, constructed of a double range of piles, with clay rammed between, for the security and convenience of the workman while digging out and building the foundation of an entrance-lock to a dock, basin, or canal, when it cannot otherwise be laid dry.

In bridge-building, the term is applied to a case of piling fixed in the bed of a river, without any bottom, for the purpose of building a pier dry. Its sides must, therefore, reach above the level of the water, and, after it is fixed, the water must be pumped out by the engines, which, unless the work is very carefully done, must be kept constantly at work, to prevent leakage as much as possible. Coffer-dams are made either double, or single. In the double one, the space between the inner and outer rows of piles is rammed with clay or chalk; the piles are driven as closely as practicable to each other by means of a pile engine, till fixed firmly into the earth; sometimes they are grooved and tongued; sometimes they are grooved in the sides, and fixed at a distance from each other, with boards let into the grooves.

The first writer on the use of coffer-dams was Alberti, who, chap. vi., book 2, gives the following directions: "Make the foundation of your piers in autumn, when the water is lowest, having first raised an enclosure to keep off the water, which may be done in this manner: drive a double row of stakes close to that side of the row which is next to the intended pier, and fill up the hollow between the two rows with rushes and mud, ramming them together so hard, that no water can get through; then, whatever you find within the enclosure—water, mud, sand, or whatever else is an hindrance to you—throw them out, and dig till you come to a solid foundation." To this we may add, where the river is rapid and deep, and the bed of solid earth or clay, the coffer-dam must be constructed with three, four, five, or even six rows of piles, according to the rapidity and depth of the stream. Due care must also be taken to brace the sides well from fixed points, as well as to make the whole water-tight, by ramming in chalk or clay, as above directed.

Where the river is rapid and deep, and the bed of a loose consistence, though the sides be never so firm, the water will ooze through the bottom in too great abundance to be taken out by the engines, recourse must therefore be had to a caisson. *See* Caisson.

The following is a description of the very large coffer-dam made at the New Houses of Parliament, for building the embankment, or river-wall. This dam was 1,236 feet long, and 10 feet wide, constructed in the following manner:—a trench was first made by dredging in the bed of the river

of the form of a segment of a circle, 27 feet wide, and 8 feet deep in the centre, to allow the piles to drive more easily; two parallel rows of guide or main piles were then driven about 5 feet apart, leaving a width of 9 feet between them transversely: to these piles were fixed three tiers of waling of whole timbers, cut down and bolted together, one tier being fixed at the top on a level with high-water mark; another level with the bed of the river: and the third midway. The piles and waling were then bolted across with iron bolts 12 feet long, forming a carcase for the inner or sheet-piling; the inner main piles being also firmly braced to resist the pressure at high water. Horizontal struts of whole timber, also, at the back of the brace piles abutted against other piles driven just within the inner edge of the foundation of the wall.

The piles were 36 feet long, driven through the gravel, and 2 feet into the clay, the top of which is 28 feet below high-water mark. Within the waling were two parallel rows of sheet-piling; the outer or river-side of whole timbers—the inner or land-side of half-timbers. After all the piles were driven, the gravel forming the bed of the river between the piling was dug out down to the clay, and the space filled in with clay, and puddled. For the purpose of pumping out the water, a ten-horse power steam-engine was erected, which was kept at work night and day; and considering the great extent of the dam, it is remarkably free from leakage. It occupied fourteen months in its construction.

COFFIN, (Greek κοφινος, a basket,) the chest or box in which dead bodies are deposited for burial. In ancient times coffins were usually constructed of stone, and sometimes highly ornamented, as is evidenced by the remains of Egyptian and other sarcophagi which have been brought to light. In England likewise stone coffins were anciently used, frequently formed of a single block hollowed out to receive the body; the shape was that of a trapezium, having the end where the head lay slightly wider than the other extremity; they were covered with a lid, which was either flat or coped, and often sculptured with crosses and other emblems. They were sometimes buried in the ground, though not deeply, sometimes only up to the lid, which was visible above ground, and sometimes placed entirely above ground.

COGGING, the same as COCKING, which see.

COIN, or QUOIN, (from the French *coin*, a corner,) the angle made by two surfaces of a stone or brick building, whether external or internal; as—the corner of two walls, the corner of an arch and a wall, the corner made by two sides of a room, &c.

COIN, *Rustic*. *See* RUSTIC.

COIN, (from the Latin, *cuneus*, a wedge,) a block cut obliquely at the bottom, but level at the top, to rest upon an inclined plane, for supporting a column, or pilaster.

COLARIN. *See* COLLARINO.

COLLAR, a ring, or cincture.

COLLAR-BEAM, a beam in the construction of a roof, above the lower ends of the rafters, or base of the roof. The tie-beam is always in a state of extension, but the collar-beam may either be in a state of compression or extension, according as the principals are with or without tie-beams. In trussed roofs collar beams are framed into queen posts; and in common roofs, into the rafters themselves. Though trusses in general have no more than one collar-beam, very large roofs may have two or three collar-beams, besides the tie-beam. Collar-beams will support or truss up the sides of the rafters, so as to keep them from sagging, without any other support; but then the tie-beam would only be supported at its extremities. In common purlin roofing, the purlins are laid in the acute angles between the rafters and the upper edges of the collar-beams. *See* TRUSS.

COLLARINO, or COLARIN, that part of a column which is included between the fillet below the ovolo of the capital, and the upper side of the astragal at the top of the shaft. The collarino is to be found in the modern Tuscan and Doric orders, but not in the three Grecian orders, except in the Ionic of the temple of Erechtheus, at Athens, and in some fragments of Ionic columns found in Asia.

The collarino, or colarin, is otherwise denominated the *neck*, *gorgerin*, or *hypotrachelion*.

COLLEGE, a public building, endowed with revenues for the education of youth and their instruction in the various branches of science and literature. An assembly of colleges constitute a university.

Our colleges consist, for the most part, of one or more quadrangular areas, surrounded by ranges of buildings, which comprise a house for the superior, and rooms or lodgings for the fellows, scholars, &c.; besides which there is always a chapel and refectory, or dining hall. Amongst our finest buildings of this class are those of Christ Church and Merton Colleges, Oxford, which, with many others at the same university, as also at the sister institution at Cambridge, are magnificent specimens of the architecture of their respective dates.

In writing on this subject, we must not pass over in silence the foundation and erection of St. Augustine's College, Canterbury, a building which may vie with many an older structure of the same kind, as well in its architectural, as its educational features.

This college comprises only one area, which is of a quadrangular form, three of its sides only being occupied with buildings, the fourth at present consists but of a wall; but the space is intended to be built upon as occasion demands. The three sides already occupied are the north, east, and west, the cortile on the southern side being enclosed by the wall; of these, the buildings on the two first, the northern and eastern sides, are elevated on a raised terrace, while those on the south are on a level with the entrance. The materials employed for the walling are for the most part flint, with dressings of rag-stone, and, in other cases, rag with Caen stone dressings. The style adopted is the Decorated of the fourteenth century; in the chapel are some parts of an earlier date, but in other respects the architecture of Edward the Third's reign predominates.

On entering under the fine old gateway on the southern side, the object which probably first attracts our attention is the long range of beautiful windows on our left. The long pile of buildings on this side of the quadrangle is raised, as we before mentioned, on a broad paved walk, or terrace, and consist besides of two stories, the lower presenting, on the exterior, a series of large, closely-set windows, with intervening buttresses; and the upper a row of nearly double the number of windows, but of much smaller dimensions, and with larger intervening spaces. The lower windows are divided by mullions into five lights, and their arched heads are filled with tracery of good design; while the windows of the upper story are of the most simple description, being but plain lancets of one light. This length of building is judiciously broken up into three parts by two stair-turrets, which give access to the apartments above; and by a door at the side, entrance is obtained to the lower story; one of the turrets is used likewise for a belfry. The doors on the terrace give entrance to a long covered ambulatory, 151 feet in length, lighted by eight fine windows, which we have noticed above, and covered with a flat roof showing the timbers, with arches spanning across at intervals where required. Out of

this cloister open twenty apartments for the students, of which above thirty more open into a corridor in the upper story. The arrangement of these apartments is the same throughout: they measure 15 feet by 8 feet 6 inches, and are divided by a partition into two rooms. The furniture of the rooms consists of an iron bedstead, a fixed and compact washhand-stand, a fixed table, having on one side drawers for clothes, and on the other a drawer for writing materials, and above the table shelves for books fixed against the wall; an elbow-chair and two others complete the furniture. The rooms are well ventilated, and heated by hot water, one of the few arrangements which we have to find fault with.

Level with these buildings, but at right angles to them, on the eastern side of the area, and detached, stands the library, perhaps the most dignified building of the whole group. Raised upon a crypt, the proportions of which are old, and the details copied and of great simplicity, is a vast apartment 78 feet long by 39 feet broad, with massy buttressed walls, and large traceried and transomed windows, surmounted by a magnificent open roof of oak, the ridge of which is 63 feet high from the level of the terrace. A noble flight of fifteen steps, approached by an ample arch, and contained within a porched roof at right angles to the main pile, and lighted by four windows, affords a means of entrance at the southern extremity. This library is well lighted by thirteen large windows, six on each side, and one at the north end; they are each of four lights, being divided vertically by a mullion, and horizontally by a transom, and have trefoiled heads. The disposition of the windows naturally divides the interior into six compartments.

The crypt upon which this building is erected, is raised on the foundation of the great refectory belonging to the ancient establishment, and is to serve the purpose of a museum. It is lighted from the exterior by small lancets, and is divided internally by ten pillars into three aisles of equal width; the ceiling is groined, and the floor paved with red tiles.

The roof of this building, as also that of the last, is tiled and crested with ridge tiles; the materials of the walling, however, vary, the library being built of uncoursed rag, with dressings of Caen, while that of the northern range is of flint.

Descending from the terrace, the most important building of the western range is the chapel, but it will be well to leave this for the present, and starting from the southern extremity of the library, follow out the lucid description afforded to us in the *Ecclesiologist*:—

"Going from this point in a south-west direction, we come to a range of buildings containing the apartments for the fellows, each of whom will have two rooms and a gyp room, and the warden's lodge, a spacious and commodious family residence. These are of flint, in good middle-pointed, and in many respects show great ability. Still we confess we think them the least admirable parts of the design. Northward of these, and projecting considerably from their level eastward into the court, is the chapel to which we shall recur after speaking of the refectory and kitchen, which range northward of the chapel between it and the ancient gateway at the north-west corner of the quadrangle. The refectory is a fine room, with a roof the humbleness of which is redeemed by its being mainly original—no oriel, (the shell of the walls being ancient,) but with a dais and tables, and a cleverly contrived range of closets at its south extremity. Northwards it communicates with a common room, and a beautiful room, intended, we believe, for a muniment-room, or, for the present, a lecture-room, occupying the upper story of the ancient gateway. Below the refectory is the kitchen, with a fine chimney projecting eastwards into the quadrangle, while offices and a porter's lodge extend under the common room to the entrance gate. A steep and narrow flight of stairs between the chapel and refectory, the kitchen door being at their feet, reaches a small landing, from the right or north of which you enter the hall, while immediately opposite, on the left hand, is the entrance to the chapel.

"The chapel is entered at the north-west, through a small ante-chapel lighted by the restored western triplet of the ancient fabric, and parted from the body of the chapel by a bold arch, sustaining a double bellcote externally, and filled with a proper screen. Within the screen extends the solemn length of the chapel, the small dimensions being quite forgotten in the beauty of the proportions: returned stalls, with miserere seats and back panelling of unexceptional style and taste, with subsellæ to match, mark the choir. Eastwards the sanctuary, though small, is beautifully treated and sufficiently dignified. The measurements are as follows: length, 60 feet; width, 18 feet; height from floor to wall-plate, 14 feet 6 inches; from floor to ridge, 30 feet 6 inches. The lighting of the chapel is peculiarly effective: a five-light middle-pointed east window, and two adjacent couplets north and south of the sanctuary, concentrate the light on the altar. The side-walls are unpierced, and the choir is consequently religiously sombre, the windows of the ante-chapel, however, sufficiently removing it from gloom. There is no colour on the walls or roof; in fact, none but the stained glass with which all the windows are filled. The whole effect is one of real, unpretending, earnest effectiveness, and austere and unworldly beauty. The stained glass chosen throughout, with a depth of meaning, itself a homily, betrays a world of thought in its distribution.

"Mr. Butterfield is peculiarly successful, we think, in his treatment of encaustic tiles. Those used in the chapel appeared to us most judiciously chosen and arranged. The footpace of the altar in particular was a beautiful mosaic of bright colours and intricate design.

"The ante-chapel is furnished with a few open seats intended for the use of the family of the warden and of the servants of the college. The choir is thus appropriated exclusively to the use of the foundation and the students.

"We rejoice to add, that there are no fixed altar-rails, though there is movable railing for the use of the communicants. A litany-stool occupies the middle of the choir. The lessons will be read from letterns fixed one on each side in the upper ranges of stalls. A rather large hole, furnished with a shutter, near the wall-plate on the north side, for ventilation, deserves notice for the boldness and simplicity of the idea.

"We should mention that the chapel is raised on a crypt vaulted and designed to serve as a sacristy. The bells are rung from a western bay, open and vaulted, occupying the space under the ante-chapel, the ropes passing through the floor by the screen, and so reaching the bells in the bellcote before noticed, which is by the way one of the less successful parts of the design.

"It is with unfeigned pleasure we again congratulate Mr. Butterfield on his success in this most interesting work, which will, we really think, ensure him enduring and most deserved fame amongst English church-architects."

COLLEGIATE CHURCH, a church to which is attached an ecclesiastical establishment of deans, wardens, and fellows, which, before the Reformation, consisted of a number of secular canons living together under the government of a dean, warden, provost, or master.

COLOGNE EARTH, a substance used by painters as a water-colour, approaching to amber in its structure, and of a deep brownish tinge.

COLONELLI (from the Italian) truss-posts, or the posts of a truss-frame.

COLONNADE, (from the Italian *colonna,*) a range of attached or insulated columns, supporting an entablature. The interval between the columns, measured by the inferior diameter of the column, is called *the intercolumniation*, and the whole area between every two columns is called *an intercolumn.* When the intercolumniation is one diameter and a half, it is called *pycnostyle*, or columns thick set; when two diameters, *systyle;* when two and a quarter, *eustyle;* when three, *diastyle;* and when four, *aræostyle*, or columns thin set. Columns are sometimes set two and two together, having half a diameter for the smaller interval, and three and a half diameters for the larger; this disposition is termed *aræosystyle.* A colonnade is also named according to the number of columns which support the entablature, or fastigium; as, when there are four columns, it is called *tetrastyle;* when six, *hexastyle;* when eight, *octastyle;* and when ten, *decastyle.* The intercolumniations of the Doric order are regulated by the number of triglyphs, placing one over every intermediate column; when there is one triglyph over the interval, it is called *monotriglyph;* when there are two, it is called *ditriglyph;* and so on, according to the progressive order of the Grecian numerals. The intercolumniation of the Grecian Doric is almost constantly the monotriglyph, for there are only two deviations from this to be met with at Athens; the one in the Doric portico, and the other in the portico forming the entrance to the Acropolis, or citadel; but these intervals only belong to the middle intercolumniations, which are both ditriglyphs, and became necessary on account of their being opposite to the principal entrances. As the character of the Grecian Doric is more massive and dignified than that of the Roman, the monotriglyph succeeds best; but in the Roman it is not so convenient, for the passage through the intercolumns would be too narrow, particularly in small buildings; the ditriglyph is therefore more generally adopted. The aræostyle is only applied to rustic structures of the Tuscan order, where the intercolumns are lintelled over with architraves. When the solid parts of the masonry of a range of arcades are decorated with the orders, the intercolumns necessarily become wide, and the intercolumniation is regulated by the breadth of the arcades and of the piers.

Buildings with a colonnade projecting at one end are termed *prostyle;* with a colonnade at both and opposite ends, *amphiprostyle;* with the same on all sides of the building, *peristyle;* and with a double range of columns, *polystyle.*

It does not appear that coupled, grouped, or clustered columns ever prevailed in the works of the ancients; though, on many occasions, they would have been much more useful; we indeed find, in the Temple of Bacchus, at Rome, columns standing as it were in pairs; but as each pair is only placed in the thickness of the wall, and not in the front, they may rather be said to be two rows of columns, one almost immediately behind the other. In the baths of Diocletian, and in the Temple of Peace, at Rome, we find groined ceilings sustained by single Corinthian columns; but such a support is both meagre and inadequate. Vignola uses the same intercolumniation in all his orders. This practice, though condemned by some, is founded upon a good principle, for it preserves a constant ratio between the columns and the intervals. Of all the kinds of intercolumniation, the eustyle was in the most general request among the ancients; and though, in modern architecture, both the eustyle and diastyle are employed, the former is still preferred in most cases: as to the pycnostyle interval, it is frequently rejected for want of room, and the aræostyle for want of giving sufficient support to the entablature.

The moderns seldom employ more than one row of columns, either in external or internal colonnades, for the back range destroys the perspective regularity of the front range; the visual rays coming from both ranges produce nothing but indistinct vision to the spectator. This confusion, in a certain degree also attends pilasters behind a row of insulated columns; but in this the relief is stronger, owing to the rotundity of the column and the flat surfaces of the pilasters. When buildings are executed on a small scale, as is frequently the case in temples, and other designs, used for the ornaments of gardens, it will be found necessary to make the intercolumniations, or at least the central one, broader than usual, in proportion to the diameter of the columns; for when the columns are placed nearer each other than three feet, the space becomes too narrow to admit more than one person conveniently.

COLISEUM, or COLOSSEUM, the amphitheatre at Rome, built by the emperors Vespasian and Titus. *See* AMPHITHEATRE.

COLOSSEUM. Although it scarcely falls within our province to describe places of amusement considered merely as such, the structure known under the name at the head of this article, deserves, from its peculiar form, and the extreme taste displayed in its interior decorations, something more than a passing notice. The Colosseum, designed by Mr. Decimus Burton, is, in external form, a polygon of sixteen sides, of which the diameter is 130 feet. In the attic, all the faces of the polygon are shown; but below, three of them are occupied by the portico, a Doric hexastyle of about 70 feet in width. This order is here exhibited upon a much larger scale than had previously been done in any building in the metropolis, with the advantage of an effect not attainable with fewer columns, and with the still greater advantage of its character not being impaired by the introduction of features irreconcileable with any aim at a strictly Grecian style, there being no other within the portico than a single lofty doorway. "In its general form," observes Mr. W. H. Leeds, whose criticisms are always entitled to attention, "this edifice must be referred to a Roman, rather than a Grecian prototype, namely, the Pantheon, which circumstance it probably was that led one writer, who has attempted to describe the building, into a ludicrous blunder, for he has not scrupled to assure his readers, that its portico is *copied* from that of the Pantheon at Rome, 'which, in the harmony of its proportions, and the exquisite beauty of its columns, surpasses every temple on the earth!' Had he said that it was copied from Canova's church at Possagno, he would have been some degrees nearer the mark, at least as far as resemblance in regard to the order adopted, and the application of a Grecian style to the plan of the Roman Pantheon."

Mr. Hosking, in his "Treatise on Architecture," objects to the combination of the square and circle in the plan; observing, "Irregular and intricate forms in works of architecture, whether internally or externally, will be found unpleasing. Few can admire the external effect of the Pantheon, or of the structure in London called the Colosseum, which has been subjected to the same arrangement, though certain features in both may be good." Yet, with due deference to the opinion of such an authority, we should be inclined to demur to it, even had we not Canova's own example to oppose to it. In itself irregularity is a fault; but then the question is, whether the slight degree of it thus produced can be fairly termed so; besides which, by pushing the doctrine a little further, we may contend that a parallelogram is an irregular square, consequently faulty, and the flank and front of a Grecian temple do not exhibit that uniformity which they might and ought to be made to do. But we need not resort

to any argument of that kind, because, were it not for the irregularity censured by that writer, and caused by the addition of a portico to the circular part of their plan, both the buildings he mentions would appear heavy, lumpish masses, whatever decoration might be bestowed upon them.

The Colosseum was built for the purpose of exhibiting a panorama of London, on a scale of magnitude hitherto unattempted. The projector made his sketches from an observatory placed on scaffolding several feet above the top of St. Paul's cross; these sketches were afterwards transferred to the canvass, and in their finished state display the whole of this vast metropolis and its environs, as it would appear on the clearest day, and aided by the most powerful vision. To use the somewhat magniloquent language of a contemporary, the spectator "sees beneath the summer sunshine of a serene sky, divested of the usual canopy of smoke and vapour, this great metropolis, with its countless multitude of streets and squares, its churches, palaces, mansions, hospitals, theatres, public offices, institutions scientific and literary; its noble river, with its numerous bridges; and in the distance a rich and varied expanse of rural and sylvan scenery, extending from the woodlands of Kent and Essex in the east, to the forest and castle of Windsor on the western horizon. Recovering from the wonder created by this first view of the picture as a whole, he finds new cause of astonishment in examining it in detail; for not only may the prominent structures be discerned and known, but every private residence in town or country, which is visible from St. Paul's itself, be recognized in the representation; and the various objects in the foreground, as well as in the distance, will bear the test of the telescope. To increase the effect, improve the convenience for inspection, and, at the same time, to augment the means of judging of the merits of the performance as a work of art, there is a succession of galleries, the highest of which is constructed for the purpose of giving a more satisfactory view of the distant country; an easy ascent from the galleries leads to an esplanade, on the circle that crowns the exterior of the Colosseum, from which is beheld a real panorama formed by the Regent's Park and its elegant vicinity."

Since the above description was written, the Colosseum, as a place of amusement, has suffered many vicissitudes, and at one time had fallen very low in public estimation; in the year 1844, however, it fell into the hands of the present proprietor, who has expended very large sums in completely remodelling the whole establishment.

The alterations considered desirable were made from the designs and under the direction of Mr. William Bradwell, whose taste, skill, and judgment have, in this instance, as in many others, produced the most admirable results. The ability he has displayed has been seconded by the proprietor with the greatest liberality, and the unhesitating appropriation of whatever amount of capital might be required to carry out the conceptions of the talented artist.

There are two entrances, one in the Regent's Park under the portico, the other in Albany Street, at the back of the building. Entering by the former, the visitor proceeds down a handsome staircase to a vestibule, leading to a large saloon, called the Glyptotheca, or Museum of Sculpture. The roof of this apartment presents to the eye a lofty dome, of several thousand feet of richly cut glass, springing from an entablature and cornice supported by numerous columns. The frieze is enriched with the whole of the Panathenaic procession from the Elgin Marbles, and is continued without interruption around the entire circumference of the hall, above which are twenty fresco paintings of allegorical subjects on panels, the mouldings, cornices, capitals of columns, and enrichments being in gold. Beyond the circle of columns is another of as many pilasters, dividing and supporting arched recesses, in each of which, as well as between the columns, are placed works of art from the studios of many eminent sculptors. In the centre of the apartment is the circular frame-work enclosing the staircase leading to the panorama; this is hung with drapery tastefully disposed, from the summit of the arched dome to the floor, concealing the stairs, and harmonizing with the prevailing tints of the architectural decorations. Around this are seats covered with rich Utrecht velvet, raised on a dais, and divided by groups of Cupid and Psyche supporting candelabra in the form of palm-trees; the figures being white, and the draperies, leaves, plumes, &c., gilded. From this hall, the visitor ascends to the panorama by the staircase, or is raised in a small room, called the *Ascending Room*, which is elevated by means of machinery to the required height.

A panorama of Paris by moonlight has now succeeded to the panorama of London before mentioned, and seems to attract as much as the former picture.

Since the creation of what may be termed the original structure, a considerable addition has been made to it on the eastern side towards Albany Street. Here is a second entrance, leading by large folding doors into a square vestibule, and thence into an arched corridor, lighted during the day from above by circles of cut glass; and at night by numerous bronze tripods. Descending to the basement story by three flights of steps, the visitor enters a spacious saloon, supported by columns and pilasters, appropriated to the sale of refreshments; from this room ornamented glass doors lead to conservatories, aviaries, and other objects of interest. In the upper story of this part of the building a handsome little theatre has been formed, the decorations of which are of the most gorgeous character. In this theatre is exhibited a moving picture called the "Cyclorama," in which a representation is given of the great earthquake at Lisbon in the year 1755. As a work of art, the panorama is deserving of high praise, and aided by the labours of the machinist, and the inventive ability of Mr. Bradwell, the presiding genius of the establishment, a scenic illusion has been produced, which is really well worthy of admiration. Altogether the Colosseum is deserving the attention of the architectural student, as something beyond a mere place of amusement. In it he may learn how much may be done in the way of decorative art, by a tasteful arrangement of those materials which the sister arts place at his disposal.

COLOSSUS, at Rhodes, a celebrated statue of Apollo, made of brass, popularly supposed to have been erected over the entrance of the harbour in such manner that a foot stood on each pier, and ships passed through its extended legs. This statue, of which Pliny has left an account, was begun by Chares, a pupil of Lysippus, and completed by Laches; twelve years were employed in making it. Its height was 105 feet; the thumb was so large that few men could span it, and its fingers were much larger than those of ordinary statues. It was cast hollow, and filled with large stones to counterbalance its weight, and keep it steady on its supporters. Within was a winding staircase ascending to the top, where it is said, was hung a vast mirror, in which the country of Syria, and ships entering the ports of Egypt, might be discerned. The notion that its legs rested one on each side of the harbour does not, however, seem to be supported by any good authority, and modern travellers do not agree as to its site.

After standing upwards of sixty years, the Colossus was overthrown by an earthquake in the year 224 B. C., by which also the buildings of the city suffered greatly. So great at that time was the commercial importance of Rhodes, that the great princes of the day vied with each other in the munificence of

their presents to repair its losses. The inhabitants of Rhodes sent ambassadors to all the states of Grecian origin, to solicit their assistance for repairing and re-erecting their statue, and obtained a sum more than five times equal to the damage. The principal contributors were the kings of Macedon, Syria, Egypt, Pontus, and Bithynia. But, instead of appropriating the money to the purpose for which it was given, the Rhodian priests pretended that the oracle of Delphi had forbidden it; and the money was converted to other uses. The Colossus, therefore, lay neglected on the ground for 894 years, when the Saracens, becoming masters of the island, sold it to a Jewish merchant, who broke it up, and loaded 900 camels with the metal: the weight of the brass, therefore, allowing 800 pounds for each load, after the diminution it had sustained by rust, and probably by theft, amounted to 720,000 pounds weight.

This enormous figure was not the only colossal statue that attracted notice in the city of Rhodes, for Pliny reckons near 100 others. From the Rhodian Apollo, it is supposed, that every statue exceeding in magnitude the size of a man, has been called a colossal statue.

COLUMBARIA, the holes left in walls for the insertion of timbers; also the recesses in ancient tombs, in which the urns containing the ashes of the deceased were deposited.

COLUMELLÆ, the same as balusters. *See* BALUSTRADE.

COLUMN (Latin, *columna*, derived from *columen*, a post, or supporter) in a general sense, a vertical support of a body, or portion of a building.

The use of columns is of very early date, as we hear of their application both in the Temple of Solomon, and in the Palace of Ulysses; they do not seem to have been employed in the primæval erections of Babylon, where their place was supplied by piers, but are to be found in universal application in the ancient structures of Egypt, India, and Persia. The column is so important a feature in the construction of buildings, that its value must have been early known, and when known, must soon have formed a subject for ornamentation; its origin is to be found doubtless in the simple pier, and a very good specimen of its progress in improvement of form and in application of ornament, is to be seen at Amada, in Nubia, where, amongst other columns or piers in the form of a simple parallelopiped, with base and capital of a similar form, but projecting a little beyond the surface of the shaft, those at the corners of the building are both cylindrical and fluted, leaving, however, a square abacus or capital, and square base, similar to the others. The former is undoubtedly the primitive shape; the latter, previously of the same form, whether for convenience or otherwise, has been rounded off at the corners and somewhat ornamented. Such improvements both in form and decoration, gradually progress, until we arrive at the well-proportioned and tastefully enriched columns of the classic orders, or the still more beautiful pillars of the Gothic styles.

The columns of Egypt exhibit a great variety, both in form and decoration: the capital in the shape of a vase or inverted bell, is usually decorated with foliage, frequently with the leaves of the lotus, but is of less elegant form than similar capitals of Greece and Rome; the shaft is generally circular, but sometimes square or polygonal, and varies in diameter at different heights, the thickness, in some cases, diminishing both towards the capital and base; this last member, the base, is frequently absent in Egyptian examples, and when present is of the simplest kind, consisting of a square slab or plinth. The columns were of stone, not unfrequently of a single block, and, at other times, of gigantic masses placed one upon the other. "There is a peculiarity, however," says Mr. Hamilton, "in the columns of the portico of Ashmounein not found, we believe, elsewhere in Egypt. Instead of being formed of large masses placed one above another, they consist of irregular pieces fitted together with such nicety, that it is difficult to detect the lines of junction; and this illusion is aided also by the form of the columns. The bottom is like the lowest leaves of the lotus, after which we see a number of concentric rings, binding the column just like the hoops of a cask; and again above them the column is worked in such a way by vertical cuttings, to present the appearance of a bundle of rods held together by hoops; the whole has the appearance of a barrel; the columns are about 40 feet high, including the capitals. Their greatest circumference is about 28½ feet, at the height of 5 feet from the ground, for the column diminishes in thickness both towards the base and capital. These columns were painted yellow, red, and blue. Similar pillars are found in the temple of Gournon."

Reeded columns, which bear the appearance of a bundle of reeds bound together at intervals and set on end, are not uncommon, and are often surmounted with a bulging capital, which is of similar formation to the shaft, with a cincture at its lowest part, and square flat abacus on the top, bearing the entablature; the swell or bulging would appear to be caused by the pressure of the entablature. Square columns are to be found in the excavations at Thebes, and triangular ones are spoken of by Pococke; at Ypsambool are square columns or piers with caryatid figures in front of them.

The forms of columns found in India vary considerably. In the subterraneous temples, which are excavated out of the solid rock, they are generally of a massive character, and in proportions stunted; they are rather grand than graceful. The bases are frequently cubical, and of great height in proportion to the shaft, sometimes equal to it; they are at other times octangular: the shafts are circular, or multangular, and sometimes consist of both forms one above the other, surmounted by low, compressed capitals. Columns of a balustral form are to be seen at the Temple of Elephanta; they are about 9 feet high, supported on cubical bases about 6 feet in height; the capitals, of a semicircular profile, exhibit the appearance of compressed cushions, and with the shafts, are ribbed or reeded: the whole is surmounted by an abacus of the form of an inverted truncated pyramid. Some very curious columns are to be seen in a cave at Ellora, which consist of elephants bearing castles, and surmounted at the top by a capital or abacus.

In the pagodas, or constructed temples of the Indians, the columns are of an entirely different appearance, they are by no means so stunted, and are often of quite an opposite character, slender; such are those in that part of the pagoda of Chillambaram called the Nerta Chabœi; they are, in all cases, profusely enriched with sculpture. The capitals of the columns are frequently made more effective to the support of the entablature by extending them out in the shape of brackets, so as to leave but a small portion of the entablature unsupported. Sometimes a succession of brackets project from the adjacent columns one above another, and meet in the centre, so as to leave no portion unsupported.

Of Persian columns we have but few examples remaining, but from these we may conclude that they were of slender proportions, the height of some of the existing specimens being as much as 70 feet, while their diameter is but 5¾ feet. Some of the shafts are fluted with fillets intervening, and are raised upon a base 4 or 5 feet in height, finished with sculptured mouldings. We have specimens of two kinds of capitals, the one consisting of small scrolls, somewhat similar to the volutes of the Ionic capital, placed in rows one above the other on the sides at the top of the shaft; the others

projecting from two opposite sides of the shaft, after the manner of brackets or corbels, and sculptured into the shape of the fore-part of an animal, which in some degree resembles a horse. These columns must have possessed a considerable share of simplicity and elegance.

Of the columns of the Grecian or Roman orders we need say nothing in this place, not only because their forms are so well known, but also because they are so fully and minutely described in other parts of this book, and amply delineated in its illustrations. Some few remarks as to their form, &c. is appended to this article.

In those styles of architecture which immediately succeeded the Roman, and were indeed but debased copies of it, the column followed the general form and character of the original; some were formed of portions of columns taken from Roman buildings, and piled together indiscriminately in the new structures, which destroyed their proportions, while it preserved their form and details. Out of this chaos arose the styles afterwards prevalent in Italy and that portion of the continent, and we may add in Greece, for doubtless Byzantine architecture, although in a certain sense a distinct style, borrowed largely, both in its general features and its details, from the edifices of the deserted capital; indeed a debased imitation of the Corinthian column was very prevalent in the buildings of Constantinople. The copy was more successful in some instances than others, the foliage being frequently of very inferior design, and only carved out slightly in relief above the surface. The more characteristic capitals of the Byzantine style consisted of mere truncated pyramids inverted and ornamented with a kind of basket-work in low relief.

In Lombardic columns the base is frequently but a simple square block, rounded off at the top, though it sometimes consists of a carved lion or other monster supporting the shaft on its back; such bases are frequent in porches and in smaller structures, as tombs, &c. The shafts, especially of the larger columns, are circular, and of the same diameter from top to bottom; the proportion between the height and diameter varies very considerably, according to the purpose of the column and its material; when the weight to be supported is great, or the material used but little compacted, the shaft is low and massive; but when the weight is inconsiderable, it becomes tall and slender, and is sometimes divided in its height by moulded bands. Columns are sometimes coupled together, standing either side by side, or one in front of the other, of both which arrangements we have examples in the cloisters of S. Lorenzo and Santa Sabina, at Rome, where either arrangement is copied in the alternate piers; quadrupled columns are to be met with in the church of Boppart. When columns are attached to walls or piers, they not unfrequently have smaller shafts either before or beside them, somewhat similar to the clustered columns of later date; these smaller shafts, however, are never prolonged in the shape of ribs of a vault. The shafts of the smaller columns are not unfrequently polygonal, fluted, or reeded, and are sometimes formed of small shafts twisted together in a spiral line. The capitals are, for the most part, barbarous imitations of the classic orders, more usually Corinthian, and are sometimes ornamented with spear-heads, and scroll or fret-work, while some again are formed of animals real and monstrous, and ornamented with grotesque designs of all descriptions.

We have now arrived at the period of Gothic art, when the forms, proportions, and ornamentation of columns became of infinite variety, subject to no law save that of beauty and utility; so that to attempt to describe them in this place would be futile. We have them of all proportions save the stunted, and of all degrees of decoration, some with simple mouldings, others with foliated capitals; some with single shafts, others clustered; some circular, others polygonal. These, as is necessary, will be considered in detail, for which we refer to the various subdivisions into which the Gothic style is usually distributed.

Column, in the orders of classic architecture, consists of a conic or conoidal frustum, called *the shaft*, tapering upwards in the manner of a tree, with an assemblage of parts at the upper extremity, termed *the capital*, and with sometimes another assemblage of parts at the lower extremity, called *the base*. The capital finishes with a horizontal table, either square on the plan, or capable of being inscribed in a square, called *the abacus*. The base, also, when there is one, most frequently stands on a table, square on the plan, and horizontal on the upper and lower sides, called *the plinth*.

Vitruvius directs the columns at the angles to be made thicker than the intermediate ones; the diameter of columns to be proportioned to the intercolumns; that the higher they are, their diminution should be less; that those on the flanks and angles have their inner faces toward the walls perpendicular, but those of the pronaos and posticum to be set perpendicular on their axes; that those in theatres and other works of gaiety, should not have the same proportion as those in sacred edifices; and that the two middle columns, opposite the entry, should have a wider interval than any two of the others.

The Greeks seldom employed attached columns; the only instances of the kind in Attica, and indeed in all Greece, are the monument of Lysicrates and the temple of Minerva Polias, where the columns present something more than half their diameter. In the temples of Agrigentum and Æsculapius, in Sicily, the columns are also attached. The remains of Roman edifices show many instances of attached columns, as in the temple of Fortune, the triumphal arch of Titus, the Coliseum, and the theatre of Marcellus, at Rome, where the columns project only half their diameter; and this rule was strictly observed by the ancients, who generally tapered the shafts from the base.

The Grecian Doric is without a base, which is peculiar to the Ionic and Corinthian orders. Much has been said concerning the proportion of columns; but it must chiefly depend upon their situation, whether disposed on the exterior or interior, attached or insulated, on a level with the eye or raised above it; circumstances which will affect the proportion, and render all canonical rules uncertain. We also judge of the proportion of columns from the materials whereof they are constructed, as a column of iron will require a different proportion from one of stone.

Some columns have the lower third quite cylindrical, and the upper two-thirds only diminished, but the most beautiful diminish from the bottom.

In the preface to Stewart's third volume of *Antiquities*, speaking of the temple of Jupiter Olympus, at Athens, Mr. Reveley, who conducted that volume, observes, that "the columns diminish from the bottom by a beautiful curve line." In another part of the same preface, he farther observes, generally, that "the columns rise, with considerable diminution, in the most graceful sweeping lines." It is much to be regretted, that Mr. Stewart, who has, in general, been so particular in the measures of Grecian architecture, should have neglected a thing so important as the dimensions of the shafts of columns.

The columns of the Pantheon, of the temples of Vesta, of Jupiter Stator, of Antoninus and Faustina, of Concord, of the arch of Titus, of the portico of Septimius, and of the theatre of Marcellus, at Rome, are all diminished from the bottom.

Columns may be diminished by a curve, according to any of the following methods:

METHOD I.—*Figure* 1. Take the semi-diameter, A B, at the top of the shaft, and apply it from C to D on the semi-diameter, C E, at the bottom; with the radius, C E, describe an arc, E F. Draw D F perpendicular to E C, divide the arc E F into any number of equal parts (as four, in this example) E *n*, *n n*, *n n*, *n* F; also divide the representative axis, C B, into the same number of equal parts, C *m*, *m m*, *m m*, *m* B; through the points *m*, *m*, &c. and also through the points *n*, draw lines *m t* and *v n*, parallel to E C, of which the lines *v n* cut the representative axis at *v;* make all the lines *m t* equal to all the lines *v n*, beginning next to the base in succession, towards A B; then through all the points, *t*, draw a curve, which is the contour of the column. The edge of the diminishing rule H, shown upon the other side, is just the reverse, that is to say, it is concave, the contour of the column being convex.

METHOD II.—*Figure* 2. The points D and F, being found, as in Figure 1, instead of dividing the arc, E F, as in Figure 1, into equal parts, divide the straight line D F into the equal parts, D *x*, *x x*, *x x*, *x* F, and the representative axis C B, into the same number, and complete the other parts of the operation, as in Figure 1. The same letters of reference being fixed to the like parts, show the process to be similar.

METHOD III.—*Figure* 3. B C being the altitude of the shaft, and B A, at right angles to it, the quantity of diminution upon one side of it: divide C B into equal parts, at the points D, E, F; also divide A B into the same number of equal parts, at the points *d*, *e*, *f;* draw the lines D G, E H, F I, parallel to A B; again from the points *d*, *e*, *f*, to the point C, draw lines, *d* G C, *e* H C, *f* I C: and through the points A, G, H, I, C, draw a curve, which will give the contour required.

METHOD IV.—*Figure* 4. A B and B C, being the same as in Figure 3: now, suppose it were required to give less curvature to the contour of the column; between A and B take any intermediate point, *g*, nearer towards A, or B, as the curvature is intended to be flatter or quicker (in this example it is in the middle of A B); draw the line *g* C, divide A *g* into any number of equal parts, A *d*, *d e*, *e f*, *f g*, (as here into four); divide B C into the same number of equal parts, B D, D E, E F, F C; draw D G, E H, F I, parallel to B A, draw *d* G C, *e* H C, *f* I C, then through the points A, G, H, I, C, draw A G H I C, which is the curve required.

METHOD V.—*Figure* 5. Join A C, and draw A L at right angles to it, meeting C B produced at L; draw A D parallel to C L, and C D perpendicular to it; divide L C and A D, each into the same number of equal parts, the former at the points E, F, G, and the latter at H, I, K; also, divide A B into the same number of equal parts, A *e*, *e f*, *f g*, *g* B; join E M H, F N I, G O K; also *e* M C, *f* N C, *g* O C, and draw A M N O C, which is the curve required.

METHOD VI.—*Figure* 6. Join A G C, and bisect it by a perpendicular, F G; on the centre, C, with the radius, C A, describe the arc A D; divide A D into two equal parts in E; draw E F C, and parallel to G A draw F I; make an angle, C F I, upon the edge of a board or rule, put in pins at the points C and F, and with a pencil, upon the angular point F, while the rule is moved from F to C, keeping the side F I of it upon the pin at F, and the same side F C, upon the pin at C, the angular point F will describe the contour of the column between F and C. In like manner, by removing the pin out of C, and putting it in A, the part F A may be described.

The same curve might have been found by one continued motion from A to C, as follows: suppose the line D C to have been produced to a point, K; the supposed line, C K, to have been equal to C D; and an angle, having been made upon the edge of a thin board, equal to A C K; then the contour, A F C, would have been described in the same manner, between the points A and C, as each of the former parts shown by the figure. It is obvious, that by this last method, it would be requisite to have the machine twice the length of that in the first method; from which it would become more unmanageable in the formation of the curve, and inconvenient in many situations, for want of space to extend it to the necessary distance.

METHOD VII.—*Figure* 7. Let A B be the representative axis of the column; A D, B C, the semi-diameters of the top and bottom of the shaft; produce C B to F; on the point D, with a radius, C B, describe an arc, cutting A B at E; draw D E F; in A B, take any number of points, *m*, and draw the lines F *m n;* make each line *m n*, equal to B C; then draw D *n n* . . . C, which will be the curve required.

METHOD VIII.—*Figure* 8. The points E and F being found as in Method VII. place a rule with a canal, or groove, on the axis A B, and put a pin in F; take another rule, D F, having a groove on the under side, and lay this groove on the pin at F; put another pin through the rod at E, into the groove A B; then, with a pencil, through D, and moving the ruler D F, while the pin E slides in the groove A B, and the groove on the under side of D F on the pin F, the contour D C, will be described with one movement.

METHOD IX.—*Figure* 9, A B being the axis of the column; A D and B C the lower and upper diameters; draw D E parallel to A B; find the point F, as in Methods VII. and VIII., and draw E C F; divide A F into any number of equal parts, by the points *g;* also divide D E into the same number of equal parts, by the points *h;* join each corresponding *g h;* make every *g i* equal to A D, and the curve drawn through all the points *i*, will be that required. This mode is practised when room cannot be found for Figures 7 and 8, with which it is the same in principle.

Observations on the several methods.—By the First Method, the curvature of the shaft becomes continually less towards the superior diameter, and if the contour were extended beyond the shaft, it would meet in a point, of which its distance from B would be a fourth proportional to the length of the arcs E F, F G, Figure 1, and the axis C B; the semi-axal section of the whole thus produced, is a figure of the same nature as the figure of the sines.

By the Second Method, the curvature of the shaft is continually increased towards the superior diameter, and if the contour were extended above A B, Figure 2, it would terminate at a distance from C, which would be a fourth proportional to D F, C *w*, C B; the contour thus produced, would be an elongated semi-ellipsis.

By the Third Method, the curvature of the shaft is continually less towards the superior diameter, and if the contour were extended, the two sides would meet in a point, whose distance from the lower end of the shaft would be the second root of a fourth proportional to the quantity of diminution, the semi-diameter at the bottom, and the square of the altitude of the shaft. The shaft and the part thus produced, forms the half of a parabolic spindle; and the axal section is two equal semi-parabolas, joined together by a common ordinate, which forms the axis of the column.

By the Fourth Method, the curvature is likewise parabolic; but the axal section is two equal portions of a parabola, less than semi-parabolas.

By Methods V. and VI., the curvature is everywhere the same, and is consequently the arc of a circle: this contour would therefore meet in a point, which would be distant from

the lower end of the shaft, by a quantity equal to the value of $\sqrt{\text{CM}\left(\frac{\text{BC}^2}{\text{AB}}+\text{AB}-\text{CM}\right)}$ in which BC is the height of the shaft, AB the quantity of diminution, and CM the semi-diameter at the bottom.

By Methods VII., VIII., and IX., the contour of the shaft never terminates when continued. The curve is concave to the axis at the bottom, and after a certain distance, it changes into a convexity. The curve is called *the conchoid of Nicomedes*, who is the reputed inventor; the straight line, in which the moving point runs, is an *assymptote;* and the point over which the moveable rule passes, is called *the pole.*

As the curve may either fall upon one side or the other of the axis, it is distinguished accordingly: when it falls on the side of the axis opposite to that in which the pole is situated, it is called *the first conchoid;* and when the describing point is made to move on the same side of the axis with the pole, the curve so formed is called *the second conchoid.*

This last method of describing a column by continued motion, has been much praised in architectural works; but though the method be simple, the instrument is very cumbersome. It may be observed, that as all curves are nearly the same at the vertex, so small a portion as is required for a column, will be the same in practice, by any of the foregoing forms. The most useful method, therefore, of describing the contour of the shaft, is that of Figure 6; the instrument is much more simple, and takes less room, which, in many cases, would not admit of that for describing the conchoid; and even that of forming the curve by one motion, as shown at the end of Method VI., is much more convenient, as length or extension in one direction only, is required. But where space is wanting, Methods III. and IV. are recommended.

Columns are variously named, according to their materials, construction, formation, decoration, disposition, and destination.

1. Columns, according to their materials, are, *moulded, fusible, transparent, scagliola, masonic,* or *wooden.*

When a column is made by cementing gravel and flints of different colours, it is called *a moulded column.*

The art of moulding columns was known to the ancients, as would appear by some lately discovered near Algiers, in the ruins of the ancient city of Cæsarea; where the same inscriptions in antique characters, and even the same defects, are to be found repeated on every shaft, which is certainly a proof of their being moulded: the cement employed in the emplastation of columns, grows perfectly hard, and receives a polish like marble.

Columns of fusible matter, as metals, glass, &c., are called *fusible columns;* the secret of making them is said to have been known to the ancients, who are also said to have fused and cast columns of stone. Columns of this description may also be called *moulded columns.*

When the material of which a column is made is transparent, the column is called a *transparent column.* The columns of the theatre of Scaurus, mentioned by Pliny, were of crystal, and those in the church of St. Mark, at Venice, are of transparent alabaster.

When columns are constructed with a kind of plaster, so as to imitate marble in polish and colour, they are called *scagliola columns.*

Columns built of rough stone, or compass bricks, and cased with stucco, are called *masonic columns,* or *columns of masonry;* as are likewise those made in courses of stone, jointed, and cemented in the best manner, with a rubbed or smoothed surface. *See* Stone Column.

When the shaft of a column is constructed of wooden staves, glued together, and the interior angles strengthened with blockings, the column is said to be *a joinery column. See* the articles Base, Capital, and Wooden Column.

2. Columns, according to their construction, are *columns in bands* or *tambours, columns in trencheons,* or *banded columns.*

When the shafts of columns are formed of courses of stone of a less height than the diameter of the column, they are called *columns in bands* or *tambours.* This method is only practised in large columns.

When shafts of columns are formed in courses of greater height than the diameter of the column, they are said to consist of *trencheons;* this is practised in small columns, when the fewer the pieces, the more beautiful will the column be; but the difficulty of raising them from the quarry is greater, and the carriage more expensive.

When the shafts of columns consist of plain or ornamented cinctures, projecting beyond the general line of the shaft, the column is said to be *banded,* and is therefore called *a banded column.* Columns of this description were first introduced by De Lorme, in the chapel de Villers-Coherets, and at the Tuileries, who by this means supposed the joints would be concealed.

3. Columns, according to their formation, are *attic, conical, conoidal, cylindrical, cylindroidal,* or *polygonal.*

The *attic column* is an insulated pilaster, having four equal faces, of the highest proportion. Though this is commonly inserted among the number of columns, it should not be so deemed, but rather what we have already denominated it, an insulated pilaster. To prevent confusion, the use of the term *column,* in architecture, should be restrained to a body of circular horizontal sections.

A conical column has the superior diameter of its shaft less than the inferior, with its sides straight in every plane passing through the axis.

A conoidal column also has the superior diameter of the shaft less than the inferior, but its exterior sides are convex in any plane passing through the axis. This practice of making the shaft swell is ancient, being mentioned obscurely by Vitruvius, and has been generally followed by modern architects.

Cylindrical columns have the extreme diameters of the shafts of equal circles.

Cylindroidal columns are those whose sections are all similar and equal ellipses, alike situated. These are otherwise called *elliptic columns.* Instances of this form are rarely to be met with in the remains of antiquity; a few examples, of modern date, are to be seen at Rome.

Polygonal columns have the horizontal sections of their shafts similar to polygons, alike situated. The lower parts of the shafts of the columns of the portico on the Island of Delos and of the temple of Cora, are of this form; as are likewise the columns of several Egyptian buildings.

4. Columns, according to the decorations of their shafts, are *bark-formed, cabled, carolytic, fluted,* or *twisted.*

A bark-formed column represents the trunk of a tree, with the bark and knots. This is otherwise denominated *a pastoral column.*

Cabled or *rudented columns* have the flutings of the shaft filled with astragals, to about one-third of their height.

Carolytic columns have foliated shafts, decorated with leaves and branches winding spirally around them, or disposed in form of crowns and festoons. They were used by

the ancients for supporting statues, whence the name. They are suitable in theatres, triumphal arches, &c.

Fluted columns have flutes cut in their sides, in planes passing through their axes, and are otherwise called *channeled* or *striated columns.*

Twisted columns make several circumvolutions in the height of the shaft, after the manner of a screw, and have sometimes several threads or screws following one another in the same circumference; they are otherwise called *spiral columns.* Vignola is said to be the first who discovered the method of drawing this kind of column by rule; but what has been presented to us by this author, is only an incorrect method of drawing the contour of the column on paper, by segments of circles, diminishing in altitude as they become more elevated in their regular succession: but the true principles of forming the shaft ought to be shown from the principles of the spiral, and described upon the conoidal surface. The barbarous practice of twisting columns has been much used by modern architects, particularly in the screens and altar-pieces of churches. The most celebrated example is the baldachin of St. Peter's.

Columns spirally formed may be seen in the temple of Spoleto, and are not unfrequent in sarcophagi and other ornamental works.

5. Columns, according to their disposition, are *angular, cantoned, coupled, doubled, engaged, flanked, grouped, inserted, insulated, median,* or *niched.*

Angular columns are insulated in the corners of a portico, or upon the corners of a building, (even though attached,) whether the angle be right, acute, or obtuse.

Cantoned columns are placed one at each corner of a square pier, for supporting the angular springings of groins, or intersecting vaults.

Coupled columns are disposed in pairs, in the same range or line, so as almost to touch at their bases; as those in the western portico of St. Paul's, and the peristyle of the Louvre.

Doubled columns, in any range of columns, or in peristyles, seem to have their shafts penetrating each other to about one-third of their diameter; as in the peristyle of the Louvre.

Engaged columns seem to penetrate a wall from between one-fourth to one-half of their diameter.

A *flanked column* has a semi-pilaster on each side of it, and is engaged from one-fourth to one-half its diameter, within the plane of the faces of the semi-pilasters.

Grouped columns stand in threes or fours on the same pedestal.

An *inserted column* is let into a wall.

An *insulated column* is free or detached on all sides.

Median columns are those two columns of a portico, which are placed in the middle of the range, at a wider interval than any other two of the same range, for giving a freer access to the principal entrance. The term is derived from *columnæ mediæ,* the name given by Vitruvius to the two columns in the middle of the colonnade.

A *niched column* is placed in a niche, with the axis of the column in the plane of the wall.

6. Columns, according to their destination, are *agricultural, astronomical, boundary* or *limetrophus, chronological, funeral, gnomonic, historical, indicative, itinerary, lactary, legal, manubiary, menian, miliary, military, phosphorical, rostral, statuary, symbolical,* or *zoophoric.*

Agricultural columns are raised for explaining the rules of agriculture.

An *astronomical column* is a cylindrical or conical observatory, built hollow, with a winding staircase ascending to an armillary sphere at the top, for observing the motions of the heavenly bodies. Such is the Doric order, erected at the Hotel de Soissons, at Paris.

Boundary or *limetrophus column* showed the limits of a kingdom, or conquered country. Such was that erected by Alexander the Great at the extremities of the Indies, mentioned by Pliny.

A *chronological column* bears an inscription of historical events, arranged in order of time. There were two columns of this kind at Athens, whereon was inscribed the history of Greece, digested into Olympiads.

A *funeral column* is placed over a tomb, supporting an urn, or bearing some inscription relative to the deceased. Its shaft is frequently covered with symbols of grief and mortality.

A *gnomonic column* is a cylinder, on which the hour of the day is represented by the shadow of a style. There are two kinds of gnomonic columns: in the one the style is fixed, and the hour-lines are projected on the cylindric surface; in the other, the style is moveable, and the hour-lines are drawn to the several heights of the sun in different seasons of the year.

An *historical* or *triumphal column* is usually adorned with basso-relievos, winding spirally upwards around the shaft, and showing the history of some great personage. The most celebrated ancient triumphal columns are those of Trajan and Antoninus Pius at Rome, and Pompey's Pillar, near Alexandria, Egypt; of modern ones we have three in London—the Monument erected in memory of the Great Fire, that erected in honour of the Duke of York, and another in memory of Lord Nelson, in whose honour there is an earlier one at Edinburgh; there is likewise a celebrated column termed Buonaparte's Column, in Paris.

Trajan's Column is of the Doric order, and constructed of marble; the face throughout its length is covered with sculptures arranged in a spiral line, running up the shaft, representing his martial exploits; its total height, including a base or pedestal of 19 feet, is 132 feet, and the diameter of the shaft at its junction with the base 13 feet.

The column of Antoninus is similar to that of Trajan both in its style and general character, though not equal to it in execution. Its height is 122 feet, including a pedestal of 26 feet, and the diameter of the shaft 11 feet 6 inches.

Pompey's Pillar at Alexandria is of the Corinthian order, and is 92 feet in total height. The shaft, which is 66 feet in height, is of a single block of granite, and polished.

Of the columns in London, the Monument is the most celebrated. It is of the Doric order, and has a fluted shaft; its total height is 202 feet, and the diameter of the shaft at its base 15 feet.

At Constantinople were two triumphal columns, similar to those of Trajan and Antoninus; that of Constantine is entirely destroyed, and of the other, erected to Arcadius, by Theodosius, only the pedestal and the first course of the shaft remain. Historical columns may also be called *memorial, honorary,* or *triumphal columns.*

An *indicative column* is placed on the sea-coast, for showing the rise and fall of the waters. Of this kind is the Nilometre, at Grand Cairo, which shows the rise and fall of the Nile.

Itinerary columns are constructed with several faces, and placed at the intersection of two or more roads, to point out the different routes by an inscription placed on each face.

The *lactary column* was erected in the herb-market at Rome, on a hollow pedestal, wherein young children, abandoned by their parents, out of poverty or inhumanity, were exposed to be brought up at the public expense.

A *legal column*, among the Lacedæmonians, was raised in a public place, inscribed with the fundamental laws of the state.

A *manubiary column* is built in imitation of a tree, and adorned with trophies taken from an enemy.

Menian columns support a balcony or meniana. This kind of column takes its name from one Menias, who having sold his house to Cato and Flaccus, when consuls, to be converted into a public edifice, reserved to himself the right of raising a column on the outside, to bear a balcony, whence he might see the public shows. We are informed of this circumstance by Suetonius and Ascanius.

Military columns were raised equidistantly on the highways from Rome to the several cities of the empire, and described their distance from the middle of the Roman Forum, as a centre, where the first military column was raised by order of Augustus. This column was of white marble, of a cylindrical form, and massive proportions, supporting a globe, the same as is now seen on the balustrade of the staircase of the Capitol at Rome. This column was called *miliarium aureum*, as having been gilt, or at least the ball, by order of Augustus. It was restored by the Emperors Vespasian and Adrian, as appears from the inscriptions.

A *military column*, among the Romans, was engraven with a list of the forces in the Roman army, ranged in order by legions, and intended to preserve the memory of the number of soldiers, and of the order observed, in any military expedition. Another kind of military column, used by the Romans, stood before the temple of Janus, at the foot whereof the consul declared war, by throwing a javelin towards the enemy's country. This column was called *columna bellica*.

A *phosphorical column* is a hollow column, built on a rock, or the tip of a mole, or other eminence, to serve as a light-house, or lantern, to a port.

A *rostral column* was a triumphal column, adorned with the beaks and prows of galleys, in memory of a naval victory. The first rostral column was erected in the Capitol, on occasion of the defeat of the Carthaginians by C. Duilius. Augustus constructed four columns with the prows of the ships taken from Cleopatra.

A *statuary column* supports a statue.

Symbolical columns represent some particular country, by appropriate attributes.

A *zoophoric column* is a kind of statuary column, bearing the figure of some animal.

There are also other columns, denominated *hydraulic*, or *water-columns*, used as fountains.

COLUMNIATED WINDING-STAIRS. *See* STAIRS.

COMA (from the Greek *κῶμα, sleep*) in antiquity, a mound of earth over a grave.

COMITIUM (Latin, *an assembly*) in Roman antiquity, a large hall in the forum, in which comitia were ordinarily held. Prior to the period of the second Punic war, it was open at the top; but on account of the assemblies being often interrupted by bad weather, it was then covered over.

COMMANDERY; a religious house belonging to the Knights Hospitallers, the same as a preceptory with the Knights' Templars. Previous to their dissolution in the time of Henry VIII., there were no less than fifty such buildings subject to the priory of St. John of Jerusalem.

COMMISSURE (from the Latin, *commissura*) the joint between two stones, or the application of the surface of one stone to that of the other.

COMMON (from the Latin, *communis*) in geometry, a line, angle, surface, or solid, which belongs equally to two or more objects.

COMMON CENTERING, a centering without trusses, having a tie-beam at the bottom; or otherwise, that which is employed in straight vaults.

COMMON JOISTS, those beams in single naked flooring to which the joists are fixed; they might be properly called *boarding-joists*, and should never exceed one foot clear of each other.

COMMON PITCH, a term applied to a roof which has the length of the sides about three-fourths of the span.

COMMON RAFTERS, those timbers in a roof to which the boarding or lathing for slating is attached. Common roofing consists entirely of common rafters, which, in the strongest-framed roofs, bridge over the purlins.

COMMUNICATING-DOORS, or DOORS OF COMMUNICATION, those which open or throw two apartments into one.

COMPARTED (from the French, *compartir*, to divide) a line, surface, or solid, divided into several parts; or a hollow space partitioned into several smaller spaces.

COMPARTITION, the distribution of the ground-plot of an edifice into apartments and passages.

COMPARTMENT (from the French, *compartiment*) a division of a picture, design, &c.

COMPARTMENT CEILING, a name given to all ceilings divided into panels, surrounded with mouldings. There are many beautiful ancient compositions of this kind applied to the intradoses of cylindrical and spherical vaulting, and to the soffits of the porticos of temples; as may be seen in the Pantheon and the Temple of Peace. The compartment ceilings of the last century were extremely heavy, which has occasioned the epithet *pondrous* to be applied to them, in order to distinguish them from those in present use. These weighty compositions took their rise in Italy, under the first masters, who seem to have been led into that idea, from observations on the soffits of the porticos of antique temples. The ancients, with their usual skill, kept up a bold and massive style, proportioning their coffers to the strength, magnitude, and height of the building, and at the same time making an allowance for their being on the exterior part, adjoining to other great objects; all which served to diminish and lighten the effect of the compartments. From this mistake of the first modern restorers in Italy, all Europe has been misled. Michael Angelo, Raphael, Pyrro, Ligerio, Dominichino, Georgio Vasari, and Algerdi, with great taste and knowledge, threw off those prejudices, and boldly aimed at restoring the antique in due proportion. But at this time, the rage for painting became so prevalent in Italy, that, instead of following these great examples, every ceiling was covered with large fresco compositions, which, though extremely fine and well painted, were much misplaced, and would, from the attitude in which they were beheld, tire the patience of every spectator. Great compositions should be placed so as to be viewed with ease. Grotesque ornaments and figures are perceived with a glance of the eye, and require little examination. The heavy compartment ceilings were afterwards adopted in France; and Le Potre adorned them with all the trappings of his luxuriant imagination. Inigo Jones introduced them into England, with as much weight, but less fancy and embellishment. Vanbourgh, Campbell, and Gibbs followed too implicitly the authority of this great name. Kent has the merit of being the first who began to introduce grotesque paintings in ornaments of stucco, and to lighten the coffers of compartment ceilings. Mr. Stewart, with his good taste in the antique, has contributed greatly towards introducing the true style of decoration; but the completion seems to have been reserved to the present times, in which not only these, but every other kind, are executed in the highest degree of perfection.

Compartment Tiles, an arrangement of white and red tiles, varnished, for the decoration of the covering of a roof.

COMPASS-HEADED, having a semicircular head.

Compass Roof, that which extends from one wall to the other the whole width of the building, having a ridge in its centre; the term is used in contradistinction to lean-to roof, and is peculiarly applied to the ancient open timher roofs. The term is applied by some to roofs with cylindrical or barrel vaults.

Compass Saw. *See* Saw.

Compass Window, a window which has a circular plan; a bow or oriel window.

COMPASSES, (from the French, *compas*) a mathematical instrument for describing circles and ellipses, or their arcs; also for measuring and proportioning distances.

Compasses for drawing are of four kinds: those with two legs, moveable on a joint, by which the extremities can be extended to any distance, not exceeding the sum of both legs, are called *common compasses.* Those with a beam having a fixed point at one of its ends, and a moveable collar carrying another point, which may be fixed at any distance from the fixed point by means of a screw, are called *beam compasses.* Those with three legs, so as to be set to any three points, of which the distance between any two may not be greater than the sum of any two legs of the compass, are called *triangular compasses.* Those for drawing ellipses, are called *elliptic compasses.*

Common compasses are of several kinds, and are furnished with fixed or moveable points, for carrying a pencil or ink foot.

Common compasses with sharp points, used for taking distances, are called *dividers.* Dividers, which have the lower point of one of the legs fastened to the upper part by a stiff spring, and by means of a screw will allow of slow motion in the legs, so as to extend or shorten the distance of the points to the smallest degree, are called *hair compasses.* Those with moveable ink and pencil feet, for describing circular lines, are called, in contradistinction, *compasses;* the ink or pencil foot is fitted into a socket in one of the legs of the compass. Besides the ink and pencil feet, there is sometimes another foot for dotting circular lines, but it is seldom used, as being apt to run two or more dots into one. Compasses for describing small circles with ink or pencil, and which shut into a bow, are called *bow compasses.*

Triangular compasses have two legs, which revolve on a folding joint, like common compasses, and the third leg is fixed to the bulb by means of a projection, with a joint, so as to be moveable in every direction. The three points of the compasses may be made almost to coincide with any three assumed points, to any distance within the reach of their extension.

Compasses with a joint between the extremities, and two sharp points at each end, forming a double compass, so that the two ends may always preserve the same ratio, however extended, are called *proportional compasses.* When the joint is fixed, the compass is said to be *simple;* but when moveable, it is called *a compound proportional compass.*

The simple proportional compasses, in most general use, have the two legs on one side of the centre always double those on the other, and are denominated *wholes-and-halves,* or *bisecting compasses.*

Compound proportional compasses have each branch cut with a long slit for a cursor to slide in; in the middle of the cursor is a screw, by which the ends may be set in any proportion to each other. One leg is generally graduated on either side of the slit, one side for the division of right lines into any number of equal parts from 2 to 10, and the other for inscribing polygons from 6 to 20 sides in a circle of any given radius within the greatest extension of the compasses. The other leg is graduated in a similar manner, one side into divisions, showing the proportion between the areas of similar plane figures, the other into parts showing the proportion between the contents of similar solid figures. This instrument is employed in the reduction of figures, and is extremely useful in the projection of dome departments, and in perspective.

Examples of the use of compound proportional compasses.—Let it be required to divide a straight line into four equal parts; push the cursor till the index be just on the figure 4, and fix it there; then take the length of the given line with the longer legs, and the distance between the points of the other legs will be one-fourth of the length of the line.

Again, let it be required to inscribe a heptagon in a circle: push the cursor till the index or zero be on 7; then, with the longer legs take the radius of the circle, and the distance between the two other points will be the side of the heptagon. *See* Projection.

To find a regular plane figure whose area shall equal one-fourth of that of a given similar figure; set the zero on the cursor to the line marked 4, take the length of one of the sides of the given figure with the longer legs, and the distance between the points of the shorter ones will give the side of a similar figure which shall contain an area equal to one-fourth of the area of the given figure.

By means of the same scale of divisions, may be found the square root of any given number, thus:—Set the zero of the cursor to the given number; open the longer legs so as to contain the same number from any scale of equal parts, then apply the points of the shorter legs to the same scale, and the distance measured between them will give the square root of the given number.

To find a sphere or cube whose solid contents shall be equal to one-fourth of those of a given square or cube: Set the zero to the division marked 4, measure the diameter of the given sphere, or the side of the given cube, with the points of the longer legs, and the points of the shorter ones will give the diameter of a sphere or side of a cube such as required.

The cube root of any number may be found by this scale in a similar manner to that by which the square root is found by the opposite one.

Compasses used in the description of ellipses, are called *elliptic compasses,* or *ellipsographs.* *See* Ellipsograph and Pentagraph.

COMPASSING (from the French, *compasser,* to encircle) in naval architecture, the act of bringing any piece of timber into the form of an arch.

COMPLEMENT (from the Latin, *complementum,* perfection) in a general sense, the full quantity, or completion of anything.

Complement, in geometry, whatever is wanting of any angle to make a right angle, or 90 degrees.

Complement of a Parallelogram, two lesser parallelograms, made by drawing two right lines parallel to the sides of the greater parallelogram, through a given point in the diagonal.

COMPLUVIUM (Latin) in ancient Roman buildings, is supposed by Newton to be the gutter of a roof; but by Dr. Adam (*Roman Antiquities*) to be the aperture at the top of the cavædium. *See* Cavædium.

COMPOSITE ARCH, the pointed or lancet arch.

Composite Base, ⎫
Composite Capital, ⎬ *See* Roman Order.
Composite Order, ⎭

COMPOSITION, the distribution and arrangement of the component parts of an architectural design.

COMPOSITION, in plastering. *See* PLASTERING.

COMPOUND ARCH, a term applied by Willis to those arches made up of a series of receding concentric arches, the dimensions contracting with each successive arch; or in other words, to those arches which may be resolved into a number of concentric archways, successively placed within and behind each other.

COMPOUND MASONRY. *See* MASONRY.

COMPOUND PIER, the same as CLUSTERED COLUMN.

COMPOUND PROPORTIONAL COMPASSES. *See* COMPASSES.

CONCAMERATE (from the Latin, *concamero*) to arch over.

CONCATENATE (from the Latin, *catena*) to chain or link together.

CONCAVE (from the Latin, *concavus*, hollow) an epithet applied to the interior side of a figure, or to the interior surface of a body.

CONCAVITY OF A CURVE LINE, the side next to a straight line, extended between the two points of a curve.

CONCAVITY OF A SOLID, the curved surface of a solid, such that if any two points be taken in that surface, the straight line between them will be entirely in a void space, or will coincide with the surface in one direction only. This definition applies to cylinders, cones, spheres, and all other solids generated by the rotation of conic sections about an axis.

When the surface of a solid is such, that two straight lines may be drawn from any point in that surface to two other points, so that the one line may be entirely in the void, and the other pass through the substance or solid, the surface may be distinguished by the epithet *concavo-convex;* of which description are the surfaces of solids formed like a trumpet-mouth.

CONCENTRIC (from the Latin, *concentricus*) in geometry, a term applied to such objects as have a common centre. It is principally used in speaking of round bodies, or figures that have a circular or elliptic circumference; and may also be applied to polygons that have the same centre, and their sides parallel to each other, about the same diagonals, radiating from the centre.

CONCHA, the concave surface of a semicircular vault, more especially applied to that of a semi-dome, or hemisphere.

CONCHOID (resembling a shell.) This name was given by the inventor, Nicomedes, to a curve, by which he proposed the finding of two mean proportionals, and the duplication of the cube. It may be described as a curve line which always approaches to a straight line but never meets it, though the straight line and the curve be ever so far produced. It is thus generated: If A P and B D be two right lines intersecting each other at right angles; and if from a fixed point, P, a number of other lines, P F D E, P F D E, &c. be also drawn, and if D E be taken equal to A B, the curve drawn through all the points E, E, E, &c. will be the first conchoid, or that of Nicomedes. In like manner, if D F, D F, &c. be taken each equal to B C, the curve passing through all the points, F, is called the second conchoid. The straight line, D D, &c. by which the description of these curves is regulated, is called *the asymptote.* The inventor, Nicomedes, contrived an instrument for describing his conchoid by a mechanical motion, of which the description will be found under COLUMN.

CONCLAVE (from the Latin) a room in the Vatican, wherein the cardinals used to meet to choose a pope. This room was, in fact, a range of small cells or apartments, standing in a line along the galleries and hall of the Vatican. The word was also used by the ancient Romans, to denote, generally, a room under lock and key.

CONCORD, *Temple of,* in Roman antiquities, a temple, built by Camillus at the foot of the Capitol, and seen from the Forum: the remains consist of a hexastyle portico, with two columns at the back, of the Ionic order; the entablature is very nearly entire; a large portion of the tympanum, and a small part of the pediment, remain at the spring of the level cornice. The weight of the tympanum is discharged from the entablature with arches. The columns are of granite, of one piece each, being 40 feet high, and 4 feet 2 inches diameter. The bases are without plinths, except those of the angular columns. The capitals are of a singular construction, and differ from all ancient examples of the same order, in having the four faces alike. The volutes are insignificantly diminutive, and the mouldings too large, compared with the other parts of the column. The architrave and frieze make only one course in height; and on the front, and at one return of the portico, are entirely plain, without any separation by mouldings. The cornice has both modillions and dentils. This is perhaps the only ancient example of the Ionic order, in which modillions are used: they are in number twenty-two in the front of the portico. An interval is placed over the axis of each column, and not a modillion; and the columns are very high, being above nine diameters and a half. This temple is supposed to have been pseudo-peripteral. The column on the right angle is less than the rest, and the middle intercolumniation greater than the others, by about one-third part of a module.

CONCRETE, the name given to a composition, variously made, but in general use among architects as an artificial foundation for buildings.

The convenience of obtaining a firm and solid bottom by the formation of a compact mass of concrete; and the facility with which this composition is made and used, have led to its almost universal adoption in all situations where the requisite materials can be procured. The proportions, and the species of material vary, of course, in different localities, and in the practice of different architects, but the principal ingredients, good lime, clean sharp river-sand, and pebbles well mixed, will not fail to make a good concrete.

Semple recommends to take 80 parts of pebbles—each about 7 or 8 ounces in weight—40 parts of sharp river-sand, and 10 of good lime; the last to be mixed with water to a thinnish consistence, and grouted in. The concrete used by builders in the neighbourhood of London, is made of Thames ballast, as taken from the bed of the river; this is found to consist nearly of 2 parts of pebbles to 1 of sand, and from one-seventh to one-eighth part of lime. Mr. Godwin says the best method of making concrete is to mix the lime, previously ground, with the ballast in a dry state; sufficient water being thrown over it to effect a perfect mixture; it should then be turned over two or three times with shovels, put into barrows, and wheeled away for instant use. It is advisable to employ two sets of men to perform this operation, with three men in each set, one man fetching the water, &c. while the other two turn over the mixture to the second set, and they, repeating the process, turn over the concrete to the barrow-men. After being put into the barrows, it should be wheeled up planks, so raised as to give it a fall of some yards, and thrown into the foundation, by which means the particles are driven closer together, and greater solidity is given to the whole mass. Soon after being thrown in, the mixture is observed usually to be in commotion, and much heat is evolved with a copious emission of vapour.

The concrete should be thrown on in layers, the first being allowed to set, before a second is thrown down. A barrow-load spreading over the ground in its fall, will form generally a stratum of from 7 to 9 inches thick, and a cubical yard of concrete will take about 30 feet cube of ballast, and $3\frac{1}{2}$ feet cube of ground lime, with a sufficient quantity of water.

Of the latter no more should be used than is absolutely necessary to effect a perfect mixture of the ingredients. Hot water accelerates the induration.

The expediency of using concrete as a substitute for stone, brick, and other materials for building, or constructions above ground, has been much discussed, and a great variety of opinion has prevailed on the subject. In the "*Prize Essay upon the Nature and Properties of Concrete and its Application to Construction*," Mr. Godwin has given much valuable information, but we think the opinions he has there ventured as to the use of concrete for walls, &c., will hardly be adopted by architects generally. "A prudent man," says Mr. Bartholomew, "will not heap up walls a second time, altogether of concrete. He will not exchange masonry of good strong mortar, and good strong stone or brick, for a heap entirely of mortar, and that "*très maigre*." A careful examination will discover that in every instance in which concrete walls have been used, more or less of instant ruin has occurred, the lintels over the apertures of the first story giving way before even those of the second story have been laid; and when those breaches have been repaired, they have reappeared; and even through the solid walls, rents have instantly occurred: experience proves that gravel lying in a bed, and there growing, as it were, without the means of flow or escape, is sufficient to support the most enormous weight of fabric; but the same gravel detached, cannot be piled up, so as to form either solid upright walls, or horizontal beams."

Concrete has been also used both as "rough concrete," and in blocks, in extensive works, as river-walls, breakwaters, &c., and has been recommended for such purposes by engineers of eminence. In the "Professional Papers of the Corps of Royal Engineers," Captain Denison describes some works of this kind, and, in the experiments he had the opportunity of witnessing, some very instructive results are obtained as to the practical application of concrete to the construction of river-walls at Woolwich and Chatham. In one instance at Woolwich, it has been applied in mass, the wall having been constructed in the same manner as the Brighton sea-wall; in both the other instances at Woolwich and Chatham, the concrete was formed into blocks, which were allowed ample time to set and harden before they were built into the face of the wall. At Woolwich, the river-wall is for the most part founded upon piles; its height above the piles is about 24 feet; the thickness at bottom 9 feet, at top 5 feet, with a slope or batter in front of 3 feet in 22. The face of the wall is composed of the blocks laid in cement, in courses 18 inches in height; the headers and stretchers in the course being each 2 feet 6 inches long: the former having a bed of 2 feet, while the latter have only 1 foot; behind the facing, the rough concrete was thrown in to complete the thickness of the wall and counter-forts. Both the blocks and the rough concrete were composed of lime and gravel, in the proportion of 1 to 7 and brought to the proper consistence with boiling water; but the blocks were, or ought to have been, made with Aberthaw lime, Dorking lime being used for the rest of the work. The blocks were cast in moulds, and were submitted to pressure while setting; a coating of finer stuff being given to the face for the sake of appearance. The whole of the wall was built by tide-work, and in the lower part therefore the backing of rough concrete had hardly time to set before it was covered with the tide; the water, however, in this instance, appeared to affect the *surface* of the mass only, the interior at the depth of a few inches appearing dry, and of a moderate degree of hardness, when examined after the retiring of the tide.

During the summer months, the action of the water from day to day was not perceptible; the surface still remained tolerably hard; occasionally portions of the fine facing separated from the rest of the block, owing, it was said, sometimes to want of care in the original construction, sometimes to injuries caused by boats or vessels striking the wall; in these cases, however, a new facing of cement was applied, and before the winter, the general appearance of the wall was to a certain extent satisfactory.

During a hard frost, however, evidences of failure began to show themselves; and as soon as the thaw allowed a thorough inspection of the face of the wall to be made, it was found that hardly a single block had escaped damage; in many instances, the whole face had peeled off to the depth of half an inch; at one spot, where a drain discharged itself into the river from a height of about six or eight feet, the back action of the water after its fall, had worn away the lower courses to the depth of some inches. These were the evidences of the action of frost and water combined, upon the best constructed wall at Woolwich. At Chatham, they were of the same character, but the damage done to the wall was much greater.

The portion of river-wall at Woolwich, which was built with rough concrete, was severely injured by the common action of the water before frost, and the same result was observed in the walls of a school near Blackheath, which were built of concrete some years ago: at the ground-line, where the drip of the water had acted, the concrete was soft, and yielded easily to any force applied, while the walls above were very fairly hard, and seemed to have stood very well. The results of the observations made at that time, on the use of concrete in constructions of a kind similar to those above mentioned, are summed up by Captain Denison in the opinion "that in climates like ours, in situations exposed to the alternate action of water and air, concrete cannot be advantageously used as a building material, the apparent economy, caused by the cheapness of the material employed, being more than compensated for by the frequency of repairs."

In the report (dated 1846) and evidence of the "Committee on the Harbour of Refuge to be constructed in Dover Bay," a great deal of valuable information is afforded on the use of concrete. Amongst the various plans submitted to the committee, Captain Denison, Colonel Jones, and Mr. Vignoles proposed to construct breakwaters of blocks of concrete. The first of these gentlemen recommended that the blocks should be manufactured at Dungeness, and thence floated to Dover by means of camels. The French adopted a similar plan in their works at Algiers, where large blocks of *bèton*, or hydraulic concrete, were floated out to the required spot, and then allowed to drop into their places from slings. These blocks were rectangular in form, and measured 324 cubic feet. At the works at St. Joilette, at Marseilles, also, immense blocks of concrete, 13 yards cubic measure in size, have been sunk for the foundation. The form suggested by Captain Denison was that of an hexagonal prism, and it was considered each block would weigh from 20 to 30 tons. The concrete would be made in the following manner:—the gravel of sea-beach to be mixed with the best hydraulic lime in the proportion of ten or twelve parts of gravel to one of lime; and with the view of causing it to set more speedily under water, a proportion of puzzolana should be added, varying in quantity according to its quality; half the quantity of puzzolana to that of lime would make very hard, sound concrete, which would set rapidly; but if desirable to make it set very quick, the quantity of puzzolana might be increased till it equalled that of the lime. The concrete used by Mr. Ranger at Woolwich was nearly the same, except that he used no puzzolana.

In the course of Captain Denison's evidence he refers to the works at Chatham and Woolwich, to which we have

already alluded, and states that he had again examined the wall at Woolwich, and found the interior as hard as could be wished. Those parts, however, of the concrete facing, which were exposed to the mechanical action of the water, were injured by it; and therefore, though recommending concrete below low-water mark, he was bound to admit that it was not adapted to those situations where it must be exposed to such action.

The specific gravity of concrete, as compared with that of other materials, is as follows:—

Concrete weighs about	140 lbs. to the cubic foot.
Brick-work	110
Granite	160 to 170
Portland stone . .	150.

We must refer to the report itself for more detailed information on this subject, only adding the conclusion come to by the committee, that "there is not sufficient experience of the use of concrete to warrant its adoption for the faces of works to be constructed in the sea."

The French engineers have made use of bèton in many of the extensive works on the continent; bèton sets very rapidly under water, and attains, after a time, a very considerable degree of hardness. M. Milet de Montville having filled a chest containing 27 cubic feet of bèton, sunk it in the sea, where it remained during two months, after which it was drawn up, to ascertain the consolidation it had acquired. On inspection it was found to be converted into so compact a body, that more difficulty was experienced in separating its parts, than those of a block of hard stone. The best manner of compounding the bèton, according to M. de Montville, is as follows:—"Take twelve parts of puzzolana, (*terrasse de Hollande, or Cendre de Tourney,*) of which form a circular wall of five or six feet in diameter, on which place six parts of sand, well sifted, free from earthy matter, and evenly spread. Fill the interior of this circle with nine parts of quick-lime, well calcined, and pulverized with an iron beetle; and to cause it to slack more quickly, (in maritime works) throw on sea-water in small quantities, stirring it from time to time with an iron spatula. As soon as it is reduced to a paste, incorporate the puzzolana and the sand. The whole being well mixed, throw in thirteen parts of unhewn stone, and three parts of iron dross, well pounded. If this latter ingredient cannot be obtained, sixteen parts of rough stones or pebbles must be added, of a size not larger than a pullet's egg. Let this composition be well amalgamated for the space of an hour, after which it must be left in heaps to coagulate; for this purpose the space of twenty-four hours will be sufficient in summer or in warm climates, but in winter it often requires the space of three or four days. Observe to keep it protected from the rain, and not to use it until it has sufficiently hardened to require breaking with a pickaxe."

The method of using the bèton is either in blocks, or by means of a coffer or chest filled with the composition, lowered to the required depth, and there emptied.

CONCRETION (from the Latin, *concresco*) the act of concreting; the process by which soft or fluid bodies become thick, consistent, solid, or hard; the act of uniting, by natural process, the small particles of matter into a mass. The word is used indifferently for induration, condensation, congelation, or coagulation.

CONCURRING, or CONGRUENT FIGURES, or SOLIDS, such as will cover each other exactly, or will fill the same space. All plane figures will do this, when their corresponding angles and sides are equal.

CONDUIT (from the French) a canal, or pipe, for the conveyance of water, or other fluid matter; an aqueduct.

The earth is full of natural conduits, for the passage of waters, which give rise to springs, and of vapours which generate metals and minerals.

Artificial conduits for water are made of lead, cast iron, stone, potters' earth, &c. *See* PLUMBERY.

Also the reservoir or erection where the waters are conducted and distributed for use. Previous to the formation of the present water-companies, these conduits were frequent in the different parts of London, and were the only means by which the inhabitants were supplied with water; the first conduit erected was one near Bow Church, Cheapside, in the reign of Henry III.; and among the latest was one of large dimensions, erected in 1655, at Leadenhall, which served likewise for an ornamental fountain. Conduits of this kind of an early date were usual in our large ecclesiastical establishments, and where cloisters existed, there was frequently one in the centre of the quadrangle; which custom has been observed in the quadrangle of S. Augustine's, Canterbury, lately erected, where the conduit, of excellent design, forms an imposing feature.

The first attempt to carry water into the houses of London was made by Peter Morris, A. D. 1582, who established the waterworks constructed under two of the arches of old London Bridge, but their supply extended only as far as Gracechurch-street; soon after, in 1594, similar works were erected near Broken Wharf, which supplied the houses in Westcheap and around S. Paul's, as far as Fleet-street. It was not until the reign of James, that any enterprise of this kind on a large scale was undertaken, when the formation of the New River was commenced by Sir Hugh Middleton in 1608, and completed in 1613.

CONE (from the Greek, κῶνος) a solid, bounded by two surfaces, one of which is a circle, called *the base*, and the other a convexity, ending in a point, called *the vertex;* and of such a nature, that a straight line applied to any point in the circumference of the base and to the vertex, will coincide with the convex surface.

The straight line drawn from the centre of the base to the vertex of the cone, is called *the axis*.

When the axis of the cone is perpendicular to the base, the cone is called *a right cone*, but when otherwise, it is called *an oblique cone*.

If a cone be cut by a plane through its vertex, the section will be a triangle.

If a cone be cut by a plane parallel to its base, the section will be a circle, or similar to the base.

If a cone be cut by a plane, so as to make the portion cut off similar to the whole cone, the section will be a circle, or similar to the base.

If a cone be cut by a plane parallel to a plane passing through the vertex, meeting the plane of the base produced without, the section is an ellipsis, except the part cut off be similar to the whole cone, as in the last position.

If a cone be cut by a plane parallel to a plane in contact with its side, the section will be a parabola.

If a cone be cut by a plane parallel to a section of the cone passing through the vertex, the section will be an hyperbola.

Every cone is one-third part of a cylinder of the same base and altitude (Euclid., b. xii., prop. 10.), and cones of equal altitudes are to each other as their bases (Euclid., b. xii., prop. 11); therefore any cone whatever is the third part of a cylinder of equal base and altitude with the cone.

The curved surface of a cone is equal to the sector of a circle, the radius of which is equal to the slanting side of the cone; and the arc-line of the sector is equal to the circumference of the base of the cone.

To find the solidity of a cone, multiply the area of the base by the altitude, and one-third of the product will give the solidity. Or, multiply one-third of the area of the base, which is the mean area, by the altitude of the cone, and the product will give the solidity. *See* CIRCLE.

To find the curved surface of a cone, multiply the slanting side of the cone by the semi-circumference of the base, and the product will be the area of the curved surface.

If the diameter of the base be given, the circumference must be found as directed under the article CIRCLE.

If the perpendicular altitude be given, the slanting side of the cone will be ascertained by the 47th prop., Book i., Euclid. But if the cone be given, it will be much easier to take the slanting side and the circumference of the base, than its altitude and diameter; the operation will also be much shorter by taking the former dimensions than the latter. *See* CONIC SECTION, ELLIPSIS, ENVELOPE, HYPERBOLA, and PARABOLA.

CONFESSIONAL, or CONFESSIONARY, in churches, a place usually under the main altar, wherein the bones of deceased saints, martyrs, and confessors were deposited.

CONFESSIONAL is also usued in the Romish church, to designate a little box, or desk, in the church, in which the priest receives the confessions of the penitents.

Few confessionals, if any, are to be found in England, although it is a common practice to set down all niches, for which no other use can be immediately discovered, under this title.

CONFIGURATION, (from the French) the exterior superficies of a body, from which it receives its particular figure.

CONGE, a concavity at the extremity of a vertical surface, where it bends off in a tangent, and projects forward until it meets a fillet, or other vertical surface, at an external angle. Thus the shaft of a column bends forward at the upper and lower ends, until it meets the fillet. The conge, when applied to a column, is part of the interior surface of a cylindrical ring, and its section is generally a quarter of a circle.

The term is derived from the French, *conge*, a curve; the Greek appellation is *apophyge;* and the Latin, *scapus*, from which the English word *scape* is derived. *See* APOPHYGE.

CONGERIES, a collection or heap of several bodies, united in one mass or aggregate.

CONGRUITY, in geometry, a term applied to lines, angles, figures, and solids, which exactly cover each other, or coincide. Figures that are equal and similar have a congruity; as have solids, the figures of whose sides are congruous with the planes of the corresponding side at the same inclination.

CONIC, relating to a cone. *See* CONE.

CONIC SECTIONS, the curves formed by the intersection of a circular cone and a plane, the former being either oblique or right. The works of Apollonius and Archimedes are the first in which these sections were treated of; and their history is nothing but that of the addition of a few remarkable properties, till the discovery that the path of a projected body in an unresisting space is a parabola, and that of a planet round the sun an ellipse. Though the name, therefore, of conic sections still remains, the interest which attaches to these curves, and the method of treating them, has no longer any reference to the accident from which they derive their name. The Greek geometers, in pure speculation, occupied themselves with the different methods in which a cone may be cut, simply because the conical (with the cylindrical and spherical) came within the restrictive definitions under which they had placed geometry;—but since the discovery to which we have alluded, we might as well attempt to write the history of mathematics and physics, as that of conic sections in their results and consequences.

Some sections of a cone are considered in elementary geometry, for a plane may meet a cone in a point, or in a single straight line, in two intersecting straight lines, or in a circle. But the curves, which are peculiarly conic sections, are the oval made by a plane which cuts the cone entirely on one side of the vertex, called the ELLIPSE; the indefinitely extended modification of this when the plane becomes parallel to any one slant side of the cone, called the PARABOLA; and the curve, which is partly on one side, and partly on the other of the vertex, formed by a plane which cuts both surfaces of the cone, called the HYPERBOLA.

Below is appended some convenient methods of forming the sections upon a plane, without any reference to the cone.

If each end of a string of greater length than the distance E F, *Plate* 1, *Figure* 1, to be tied to the points E and F, and any intermediate point B, be taken in the string, then the point B being carried round the line E F, so as to keep the parts, E B, B F, always stretched till it come to the point whence it began to move, the point B will trace out a curve, A B C D, which will be *an ellipsis.*

If the end of a straight inflexible line, or rod, of a greater length than the distance E F, *Figure* 2, be fixed to one extremity, E, of the line, and one end of a string of greater length than the difference between E F and the length of the rod, be fixed to F, and the other end to the other end of the rod at N; then, if any point, B, be taken in the string, and the rod moved round the point E, so as to keep the parts N B, B F always stretched, the point B will trace out a curve, which will be *an hyperbola.*

And if the end of the rod be moved from E, and fixed at F, and one end of the string moved from F, and fixed at E, the curve described after the same manner, is called *an apposite hyperbola.*

In the ellipsis and hyperbola, the points E and F are called *the foci;* the line, A C, passing through the foci, joining the opposite parts of the curve, or curves, is called *the transverse axis;* and the point, C, in the middle of the transverse axis, is called *the centre.*

In the ellipsis, any line drawn through the centre, and terminated by the opposite parts of the curve, is called *a diameter;* if another right line, terminated by the curve, be drawn parallel to a tangent at one extremity of the other diameter, such line is called *a double ordinate;* and if it pass through the centre, it becomes *a diameter;* then the two diameters, thus situated, are called *conjugate diameters.*

When the conjugate diameters are at right angles to each other, they are called *the axis of the curve.*

If there be a diameter, and a double ordinate to that diameter, the two segments of the diameter are called *the abscissæ.*

Concentric ellipses are such as are similar, and have the same centre with the greater axis of the one upon the greater axis of the other, and the less upon the less.

Most of the above definitions apply also to the hyperbola.

If the side, A B, *Figure* 3, of a right angle or square, A B C, be applied to the straight-edge, A D, of a rule, and a thread, equal in length to B C, be fastened to the end, C, of the right angle, with the other end to the fixed point, F; and if any point, E, be taken in the line, then if the edge, A B, of the square be moved along the straight-edge, A D, keeping the variable point, E, upon the side, B C, of the square, and the two portions C E and E F stretched, the point E will trace out a curve, which is a parabola.

The point F is called *the focus.*

The line A D is *the directrix.*

The line L K passing through the focus perpendicular to the directrix, is *the axis.*

The point I, where the axis cuts the curve, is *the vertex.*

Any line parallel to the axis, terminated at one extremity by the curve, and on the concave side of it, is called, *a diameter.*

Any line parallel to a tangent at the limited end of a diameter, is called *a double ordinate* to that diameter.

The limited part of a diameter, contained by the curve and a double ordinate, is called *the abscissa* of that double ordinate.

Figures 4, 5, 6. *An abscissa, the ordinate, and the diameter being given, to describe the ellipsis or hyperbola.*

Let A B be the diameter, A C the abscissa, and C D the ordinate. Draw A E parallel to C D, and D E parallel to C A. In D C take any number of points, F, G, H, and divide D E in the same proportion at *f, g, h.* Draw B F I, B G K, B H L; likewise *f* I A, *g* K A, *h* L A, and through the points D, I, K, L, A, draw a curve. In the same manner may the curve for the opposite ordinate be drawn.

When the extremities of the diameter are on different sides of the ordinate, the curve is an ellipsis; but when the extremities of the diameter are on the same side of the ordinate, the curve is an hyperbola. When the diameter A B, is of infinite length, the ordinates, F I, G K, H L, will be parallel, then the curve is a parabola. Therefore, in *Figure* 4, the lines drawn from the points F, G, H, parallel to the transverse axis, or abscissa, A B, instead of being drawn to the point B, as in *Figures* 1, 2, 3, make the only difference.

It is hardly possible to conceive more convenient or easiei modes of description than these; their correctness may be proved by showing that their common properties are similar to those demonstrated of conic sections.

Figures 7, 8, 9.—Let A B be the diameter, C D the ordinate, and A C the abscissa, as before. In C D take any point, G, and divide D E by *g*, in the same ratio as D C is by the point, G; draw *g* K A, B G K, *Figure* 7, and B K G, *Figure* 8; then, because of the similar triangles, B N K and B C G, B N : B C : : N K : C G; and also, because of the similar triangles A N K and A M G, A N : A M or *g* E : : N K : M G or C D. By construction we have *g* E : D E or E A : : C G : C D; and therefore by multiplication we have $BN + NA : BC + BA :: NK^2 : CD^2$, which property is known to be that of the ellipsis and hyperbola.

Corollary.—Since, in the parabola, B N and B C are of infinite length, and may therefore be said to be equal, B N and B C may therefore be expunged from the first two terms of the analogy in the above general property; then we shall have $NA : CA :: NK^2 : CD^2$.

Or the truth of the operation may be shown by a particular demonstration for the parabola thus: *See Figure* 9.

Because of the similar triangles A N K and A M *g*, A N : A E : : N K : M *g* or C D; by construction we have A M : A C : : C G or N K : C D; and consequently, by multiplication, $AN : AC :: NK^2 : CD^2$, which is the property of the parabola.

Figures 7, 8, 9.—*In a conic section, are given the abscissa,* A C, *an ordinate,* C D, *and a point,* K, *in the curve: to determine the species, and thenøe to describe the curve.*

Draw E *g* D parallel to A C, and A E parallel to C D; through the points A and K draw A K *g*, cutting E D at *g*; make D G : G C : : D *g* : *g* E, and through the points K and G draw K G B or G K B, which, if not parallel to A C, produce it until it meet A C or C A in B; then A B will be a diameter. In this case the curve is an ellipsis or hyperbola. It is an ellipsis when the extremities of the diameter are on different sides of the ordinate, as in *Figure* 5; but when the extremities of the diameter are on the same side of the ordinate, the curve is an hyperbola. If K G be parallel to A C, the curve is a parabola. A diameter, A B, and an ordinate, C D, being thus ascertained, the curve will be described as in *Figures* 1, 2, 3. Other particulars relating to these curves will be found under the articles ELLIPSIS, HYPERBOLA, and PARABOLA.

CONICAL ROOF, a roof whose exterior surface is shaped like a cone.

CONICS. *See* CONIC SECTION.

CONISTRA, the pit of a theatre.

CONJUGATE DIAMETERS, of an ellipsis or hyperbola, any two diameters that are parallel to tangents at the extremities of each other.

CONOID, (from the Greek, κωνοειδης, *partaking of the figure of a cone*), a figure generated by the revolution of a conic section round one of its axes. There are three kinds of conoids, viz., the elliptical, the hyperbolical, and the parabolical; which are sometimes otherwise denominated, *ellipsoid,* or *spheroid, hyperboloid,* and *paraboloid.*

Now because the solid is generated by the revolution of the section of a cone upon its axis, the axis will then also be that of the solid. In this case, since, in the generation of the solid, every point of the curve will describe a circle, every section of the solid parallel to the base will be a circle.

If a conoid be cut by a plane meeting the base, or the plane of the base produced, the section will be either an ellipsis, or an hyperbola, or a parabola.

Every section of an ellipsoid oblique to its axis, is an ellipsis; and if a paraboloid or hyperboloid be cut by a plane meeting the plane of the base, produced on the outside of the figure, the section will also be an ellipsis. In the paraboloid, if the cutting plane be parallel to the axis, the section will be an equal parabola. In the hyperboloid, if the solid be cut by a plane parallel to a section of the cone, made by a plane passing through the point where the asymptote of the generating section meets the axis of the solid produced, the section will be an hyperbola; but if the cutting plane be parallel to the plane in which is the asymptote, and at right angles with the generating section, the section will be a parabola.

Thus the ellipsoid has only two sections, viz. the circle and the ellipsis: the paraboloid, three sections, viz. the circle, the ellipsis, and the parabola: the hyperboloid, four sections, viz. the circle, the ellipsis, the hyperbola, and the parabola: and the cone itself has five sections, viz. the triangle, the circle, the ellipsis, the hyperbola, and the parabola. The triangle is a section peculiar to the cone alone; the hyperbola, to the cone and hyperboloid; the parabola, to the cone and parabolical and hyperbolical conoids; and the circle and ellipsis are common not only to the cone, but also to each of the three conoids.

All parallel sections of conoids are of similar figures; though it may seem singular that this should be a general property, when it is considered that, in a cone, a section through the apex, or point, is a triangle, and a section parallel thereto is an hyperbola; so that if the property existed generally, the triangular and hyperbolic sections of the cone so posited ought also to be similar. To reconcile this paradox, let us consider, that in all hyperbolical parallel sections of a cone, the asymptotes make equal angles, and the sections which are nearer to that passing through the apex of the cone, have a greater degree of curvature at the vertex of these curves, than those which are more remote, though both figures be similar. Farther, if the legs of the hyperbola be infinitely extended, they will be infinitely near a straight line, as they will fall in with the asymptotes nearly, and the curved portion will bear no sensible magnitude, compared with the part which is comparatively straight, as the legs of the hyperbola

become straighter and straighter as they are more and more produced. Thus the curved portion may be considered as a mere point to the whole figure, in a section through the vertex, the ideas of the general property seeming to vanish, or not apply; but if we allow a parallel section, though ever so little distant, it can very easily be compared with any remote parallel section, and their difference will be this, that, in like portions of the two curves, the similar figures inscribed in the section nearer to the apex will be incomparably small to those of the sections more remote, and in a parallel section passing through the vertex, the similar figures of comparison will be lost, as being of infinitely small magnitude.

The section through the axis, which is the generating plane, is, in the spheroid, the greatest of all the parallel sections; but in the hyperboloid, it is the least; and in the paraboloid, it is equal to any other parallel section.

If an hyperbola be supposed to revolve with its asymptote upon its axis, the curve will generate a conoid, and the asymptote a cone; and if these two solids be imagined to be cut by a plane in any position, then the two sections will be similar and concentric figures, of the same species in each solid.

To find the solidity of a conoid.—To the area of the base, add four times the area of the middle section, multiply one-sixth of the sum by the height, and the product will give the solidity. In the spheroid, one-sixth of four times the middle section only, multiplied by the height, gives the solidity; that is, two-thirds of the circumscribing cylinder.

Other particular rules and properties will be found under Ellipsoid, Paraboloid, and Hyperboloid.

CONOPEUM, in antiquity, a sort of canopy of net-work, hung about beds, to keep away gnats and flies.

CONSERVATORY (from the Latin, *conservo*, to keep) may be defined generally as a place for preserving anything in a state desired, as from loss, decay or injury; in this sense, granaries for keeping corn, ice-houses, &c., may be called conservatories.

In gardening, the word conservatory is so frequently confounded with Green-House, and the terms are applied with so little precision to buildings used for preserving plants in an artificial climate, that it is difficult to define what is properly a conservatory. "The term," says a writer in the *Penny Cyclopœdia*, "which, as its meaning shows, was originally intended for buildings in which plants were preserved during winter, has come to be used, firstly, for glass houses in which plants are cultivated by growing them in the open border, and subsequently for all such glazed buildings whatsoever. A conservatory, properly so called, is a brick building heated by artificial means, having its whole southern part closed by large glazed sashes, which may be opened or shut at pleasure. Its floor is generally of stone, and a part of it is occupied by a stage on which plants in pots can be placed. Such a conservatory was intended to preserve during the winter, orange-trees, myrtles, American aloes, and similar plants, which during the summer will flourish in the open air, but which require during the winter to be protected."

The modern or popular meaning of the word, is now almost the opposite of the original one, and a conservatory is said to differ from a green-house principally in this, that in the latter the plants and trees stand in pots, placed upon stages; and in the former are regularly planted in beds of the finest composts, on being removed from the green-house, and taken out of the tubs or pots. By introducing stages, instead of beds, however, one may serve for the other.

The construction of a conservatory is similar to that of a green-house; but it should be more spacious, elevated, and finished in a superior style. The sides, ends, and roofs should be of glass, in order to admit light freely, and to protect the plants. It should likewise be so situated as to be quite dry, receiving as much of the heat of the sun as possible during the day, and provided with flues to communicate heat when found necessary, and valves and other conveniences for the introduction of fresh air, when required, for the purpose of ventilation. In summer-time, the glass roofs are sometimes taken off, and the plants exposed to the open air, but on the approach of the autumnal frosts, they must be restored.

There is much diversity of opinion amongst practical men as to the comparative merits of wood and iron in the construction of conservatories. Mr. J. Thompson, a man of great experience, in his "Practical Treatise," gives the preference to wood, although acknowledging the advantages of iron in lightness of appearance. "Any persons," he observes, "having a knowledge of the expansion and contraction of metals, may form some idea of the expansion of a large iron roof on a hot day during the months of July and August, and of the contraction on a severe frosty night; so great have I witnessed the action of the sun's rays in expanding the iron rafters and lights upon a hot day, that it has required two or three men to draw down the sliding-lights; and in an equal proportion have I seen the contraction during the intensity of winter, so much so, that large apertures have appeared between the rafters and lights, which admitted the external air to such an extent, that it required the strength of two fires, and the flues heated to the greatest excess, before the house could be raised three degrees of heat, and this in a house of not very large dimensions." This gentleman also objects to the iron-roofed houses, that they require double the quantity of fuel that is necessary in houses otherwise constructed. Notwithstanding some admitted disadvantages, the great convenience of iron, the readiness with which it is manufactured, and the extreme lightness and elegance of its appearance, will always give it a great advantage. Some of the most mugnificent conservatories in this country, have been constructed of iron, amongst which we may especially notice that in the Botanic Garden, Regent's Park.

This building was erected under the direction of Mr. Decimus Burton, and forms the half of the centre part of the proposed "Winter Garden," in which, when completed, the subscribers to these beautiful gardens will be able to enjoy the luxury of the parterre at all seasons of the year.

It is constructed of iron, principally wrought, the pillars and guttering only being cast. The water from the roof is conducted by the internal pillars, to large tanks under ground, from whence it is pumped up for the supply of the house. The building is heated by warm water conveyed through pipes arranged beneath the surface, in brick channels, having large outlets for the hot air, with air-ducts at intervals to create a current, and give increased action to the hot air in the drains. The boiler-house is beneath the ground, at some distance from the building.

The structure is ventilated by sliding-lights in the roof, acted on by a simple contrivance, which opens and shuts the whole simultaneously, and is glazed with sheet-glass in long lengths.

The whole building contains above eleven thousand superficial feet. It was erected by Mr. Turner, of the Hammersmith Ironworks, Dublin, at a cost of about £6,000.

The conservatories at Sion House, the Duke of Northumberland's, Alton Towers, the Earl of Shrewsbury's, and the Duke of Devonshire's at Chatsworth, are on the most magnificent scale, and are especially worthy the study of the young architect who may be called on for designs for a build-

ing of this description. He will also find much valuable practical information in Mr. J. W. Thompson's work on the "*Construction of Stoves, and other Horticultural Buildings.*"

The conveniences which may be attached to conservatories, consist of retiring-rooms, seed-rooms, aviaries, &c. If there be no sheds behind, the walls should not be less than three bricks thick.

CONSISTORY (from the Latin, *consistorium*) a large hall, at Rome, in which the college of cardinals meet to plead judiciary causes.

CONSOLE (from the French) a bracket, or projecting body, formed like a curve of contrary flexure, scrolled at the ends, used for supporting a cornice, bust, or vase.

Consoles have been used for supporting an entire order of columns, as in the barbarous architecture of the palace of Diocletian, at Spalatro.

Consoles are otherwise denominated *ancones*, or *trusses*.

CONSPIRING POWERS, in mechanics, such powers as act in directions not opposite to each other.

CONSTRUCTION (Latin, *construo*, to heap up into one) the erection or disposition of several separate parts in such a manner, as to form a perfect and compact whole.

A good knowledge of the principles of construction, forms an essential item in the qualification of an architect. The principles of construction arise out of and are entirely dependent upon those of gravitation. "Gravity," says an excellent authority on this subject, "is the source of all the principles, inventions, and ingenuity, called into action in the structure of architectural works. The weight or downward tendency of their materials, is the cause of buildings holding together, or falling, or being thrust apart. Gravity, in its various dynamic modifications, is the sole acting power which operates in a building. All the mechanical perfections of scientific building result from a clear knowledge of the operation of gravity, and from the ability to direct their course: all the mechanical defects of buildings, result from an ignorance of the laws of gravity, and from inattention or inability to counterbalance their effect. A judicious architect enslaves to his purpose the active force of gravity, and compels it to exert all its force in holding together more firmly his structure; an ignorant or careless architect or workman, allows that force to exert itself in wracking, straining, distorting, breaking, and destroying his work."

The methods in which gravity acts upon materials, are by compression, by tension, and by cross-strain. The first of these modes of operation is the simplest and least destructive, unless exerted to too great an extent, and is that which forms the basis of the most sound construction; its tendency is to bring the particles of matter more closely together; instances of its application occur in all simple constructions, such as upright piers, arches, &c. The second method, that of tension, has a directly opposite tendency to the last, and exerts its influence in disengaging the atoms from each other, it is of course not naturally favourable to construction, but the contrary, nevertheless it is made a very efficient and useful agent; its influence is never exerted but upon materials which have a strong counteracting tendency, and it is made available to produce the first effect of gravity, or compression. Examples of its operation are to be met with in suspension-bridges, and in the tie-beams and king or queen-posts of trusses. The third method by which materials are affected by gravity, is cross-strain, which is a combination of the two last, as it is tension effected by pressure, and its result is to tear or wrench the particles of matter asunder; it is in principle totally inimical to construction, and must be avoided or counteracted. Cross-strain occurs in unscientifically formed roofs, where struts rest upon a tie-beam, also when any vertical weight presses upon any horizontal beam, as in the case of brest-summers; it happens likewise, when heavy untrussed horizontal beams have too great a bearing, the effect in this case is termed sagging, and is counteracted by cambering or trussing the beam.

Analogous, and arising out of these operations of gravity are the three great principles in construction—repose, equipoise, and tie. The first of these is the simplest, and is the principle most usually adopted in very ancient buildings; it is used where the materials are merely piled up perpendicularly, so as to form piers or columns with cross-beams, architraves, or lintels, laid horizontally upon the piers or columns, pressing downwards merely with the gravity of these materials, without any thrust or other inclination to destroy the position of any part of the arrangement. "Buildings constructed on this principle, need only tenacity of material and unflinching foundations to be altogether perfect in construction; but buildings of this kind, owing nothing to geometrical science, lead to an enormous consumption of materials; all the materials of the horizontal spanning masses, of even a small building, must be huge, and are thence immensely expensive to procure, and to raise to their destined places; if these spanning masses be either so long or so brittle as to yield by their own weight, or by that which may be put upon them, the principle of simple repose becomes destroyed; the horizontal masses sink, and the piers or sustaining masses are thrust outwardly."

The disadvantages attending this mode of construction, led to the invention of others, yet at the same time they all aimed at attaining the same end, namely, simple repose throughout the materials and different members of a building. The principle of equipoise in construction is this, that all tendencies to disturb or produce motion amongst the parts of a structure, should be counterbalanced by an equal and opposite tendency, and the most perfect exhibition of its powers is to be seen in the arch. This principle of building allows of the employment of the smallest materials, and ensures stability with the least possible quantity of matter; it is therefore far preferable to the first method or principle. The third principle, of tying, is of modern invention, and by it the quiescent state of a structure is maintained, not by resisting the power as in the last case, by external opposition or abutments, but by confining the power by internal restraint. The principle is embodied in the structure termed a truss.

The most perfect specimens of constructive science are to be found in the wonderful erections of the Gothic architects: "The mediæval Christian builders arrived to such a delicate and intimate acquaintance with architectural dynamics, that by the discovery of the way in which all the particles of their materials were affected by gravity, they were enabled, by merely subjecting them to the frangibility caused by compression, so to economize them, and reduce their quantity, that many members of Gothic edifices, after five hundred years' devastation by time, are more sound than corresponding members of our modern builders, which have not subsisted fifty years, and which contain five times their proportion of materials. So admirable in general is the skill displayed in the dynamic disposition of the material of a Gothic cathedral, so shrewdly are the forces of its gravitation reduced to simple compression, that the whole is like a wonderful piece of shoring, sublimely and permanently imitated in stone."

CONSTRUCTION, the art of describing a diagram or scheme from given data.

In geometrical constructions, the accuracy of the diagram depends upon that of the points by which the lines constituting the figure are found. It is, therefore, of the utmost consequence to ascertain the situation of points correctly by lines crossing at right angles, or as nearly so as possible.

The choice of this is not at all times in the power of the geometer, but when it is, he ought to avail himself of it. The situation of a point must be ascertained by the intersection of two lines, and since a line cannot be without breadth, it will be an oblong, and the intersection of two lines will be a parallelogram; when the lines cross at right angles, the parallelogram will form a square; and when at oblique angles it will be a rhombus. In all those cases, the point required is in the intersection of the diagonals of the parallelogram. Now the least of all the parallelograms formed by the intersection of two lines of equal breadth, is a square; but the greater the obliquity of the lines of intersection, the longer will be the rhombus; and as the drawing of the figure depends upon vision, the more indistinct will the angles of the figure so formed become, and consequently the situation of the point must be almost guessed at. In some cases, the obliquity of the intersection is of little consequence; as, in finding a curve by points, where the lines, which form the intersection, fall very nearly in with the curve itself, or make very acute angles with the tangent, unless it be required to find the points in the curve in a given ratio; but if, in finding a point, through which a line is to pass from another given point, to meet a line, of which some parts are either given or found, or to be found, it will be of the utmost consequence to determine with accuracy the situation of the intermediate point; for the point asertained in the other line will vary from its true place, more or less, according to the distance of the intermediate point found by the intersection.

Another source of error arising from the intersection of oblique lines, which will also be more or less accurate, as the obliquity is less or greater, is, when one or both the lines are not exactly drawn through their extremities; even the deviation of a line being drawn its own breadth, will make the intersection fall its own length (which is the diagonal of the rhombus) to the end of the true intersection. Let it also be considered, that the longer diagonal of the rhombus may be of any length whatever, depending upon the obliquity of angles formed by the two intersecting lines. In the description of a diagram, when different points are ascertained in a line, in pointing out the line to the reader, it would be better to name all the letters in the order as they stand, instead of pointing out the line by two of the letters, particularly in a complicated diagram, where many other lines are concerned. This is still more necessary when several lines meet at the same point, as the use of all the letters not only gives a more immediate clue to identify the lines from others, but also shortens the description, as the same letters must be used again, in pointing out the other lines which cross the former line, and will thus supersede the necessity of the frequent repetition, after a line has been drawn in the required position to cut a former, of saying, "cutting such a line in the point" A or B, or whatever it may be; as the same letter cannot be in two lines, except at their intersection.

In tracing the boundaries of angular figures, it will only be necessary to name the letters progressively, as they stand at the extremities of the sides, that is, at the angles; but to trace out the whole enclosure or perimeter, it would be necessary to name the first letter again, at the end of the series of letters. It is true, that a triangle, a quadrilateral, &c., will easily be understood, without naming the first letter again, by naming the figure at the same time, or the number of its sides, as in polygons the last side will always be wanting.

Though these enumerations and repetitions of letters may appear clumsy, they lead sooner to an understanding of the construction, shorten the language, and give accuracy to the description.

CONSTRUCTIVE CARPENTRY shows the method of reducing wood into forms, and joining the parts, as directed by the rules of DESCRIPTIVE CARPENTRY, or by the laws of strength, and thereby forming a complete design.

It is much to be regretted that the first principles of this department of the art are frequently so little understood by those who are called upon to put them into practice. The young carpenter too often follows blindly in the track of those who have gone before him, without inquiry, and without even attempting to understand the mechanical construction of the work he has just put together. We do not mean that the practical builder must necessarily make himself master of the higher branches of science, but that it would obviously be of advantage to him that he should acquire that general knowledge of the elementary principles of the art, which would enable him to select the best materials, and employ them in the best manner.

Every species of construction should be characterized by stability, and a careful regard to economy of materials. These objects can only be obtained by judicious combinations of the substances used, so that the greatest amount of strength be secured with the smallest expenditure of material. Unless the builder possess a considerable knowledge of the principles of mechanics, unless he be acquainted with the effect of pressure, and the resisting powers of different materials, he cannot comprehend, much less design, such combination; but becomes a mere labourer putting together the several parts of a work, without knowing their relative dependence on each other, or the strength, or want of strength, of the whole. He is, indeed, from the want of such knowledge as we have described, incapable of judging what are the best forms of construction, or which of several modes of uniting timbers it is most advisable to make use of. It is the province of constructive carpentry to show this, and the carpenter who is desirous to make himself thoroughly acquainted with his business, should study to acquire not only a practical knowledge of its details, but also some insight into the principles on which it is founded.

Constructive carpentry, it has been observed, is the method of reducing wood into forms, and the combining of several parts into a complete, firm whole. In most works, especially those of magnitude, it will frequently be necessary to join one or more pieces of timber, in order to obtain beams, &c., of sufficient size, and in order to economize material. The processes by which these objects are effected is a subject of the greatest importance, as on their being properly and substantially performed depends the stability of the structure in which they are used. Under this article then we propose to describe some of the most approved methods of uniting timber, and to treat of the following operations, viz., the lengthening of beams, either by scarfing or joining them in pieces; the strengthening of beams by trussing; the methods of joining two timbers at angles, in any given direction; and lastly, the mode of connecting several timbers, in order to perform certain functions required by the design.

To lengthen a piece of timber, is to join or fasten two separate pieces, so that a portion of the end of the one piece shall lap upon a portion of the end of the other, the sides of both making but one continued surface, and forming a close joint, called a *scarf*.

It is evident, that in the formation of a continued straight timber, if the joint consist of a plane, or planes, at right angles to two opposite sides of the compound piece, but not at right angles to the plane of the other two opposite sides, the plane, or several planes, forming the scarf, will make the

oblique angles, constituted by the surface of each piece on the same side, supplements to each other: or whatever oblique angle or angles the one piece makes with a side, the corresponding angle or angles formed by the joint or joints with the same continued surface of the other, will, together, form two right angles, and thus the solid part of the one will be equal and similar to the void of the other.

There are several methods of lengthening timber, either by joining whole pieces of the same transverse sections, and forming their ends, which are to come in contact in one or several planes, or by forming the connection by means of a third piece, or by building the piece to be lengthened in several thicknesses, making the joints abutting upon each other on the solid of the piece with which they come in contact on the parallel joint. It is evident, that two bodies united, and intended to act as one in a state of tension, can never be so strong as either piece taken separately.

Tabling is a mode of indenting the ends of the pieces which form the scarf, so as to resist a longitudinal strain; the pieces, therefore, require to be held together, or otherwise the notches and the tables which fit into them would require to be dovetailed. In this construction, the tables between the notches would be a very feeble support, as they are apt to split away. It must also be observed, that one single table, or one abutting part of resistance, is stronger, and much more easy to execute, than two or four; and that the resisting part should have as little projection as possible, because such projection diminishes the cohesive force, by a quantity of the timber equal in section to the abutting parts. Two pieces of timber may be very firmly fixed, by making the ends of the tables, instead of abutting, to form a tapering mortise, so that when the two pieces are brought close at the connecting surfaces, a wedge driven into the cavity will bring all the parts of the joint into contact.

Every two pieces of timber require to be held together by some force compressing them equally on each side, particularly when the pieces are light; for which purpose iron bolts are very convenient, they acting as a tie, and having the same effect as two equal and opposite forces would have in compressing the beam on each side of the scarf; and as iron is of great strength, the bore made to receive the bolt will not be so large as to diminish the section, and consequently the firmness of the timber at the scarf, in any considerable degree; whereas, when wooden pins are used, they require a large bore, which weakens the timber, and the two pieces thus connected are not so firmly compressed, or, indeed, compressed at all, but are held together almost solely by friction.

No limited distance can be specified for the length of the scarf; though it may be observed, generally, that a long scarf has no effect in diminishing the cohesive strength of a compound piece of timber. On the contrary, a long scarf gives an opportunity of increasing the number of bolts, which are the only ties when no tablings are used, as is the case where the abutting parts unite only by compression. It must here be understood, that all such abutting parts diminish the cohesive force in the proportion of their abutting surface to that of the whole section at any one of the abutments; so that should a scarf consist of a series of steps, formed by planes parallel and perpendicular to two of the opposite sides, the transverse sides of these steps to those of the piece should be all equal; and the greater the number of steps, the less will the strength be impaired; but if they be unequal, the timber will be weakest at the greatest section or compressed abutment, and if few, the section will be large, and the piece consequently deprived of a proportional degree of strength. We may also add, if the two pieces be strapped longitudinally across their abutting parts, the cohesive force will be considerably assisted thereby.

There is no part of carpentry which requires greater correctness in workmanship than scarfing; as all the indents should bear equally, otherwise the greater part of the strength will be lost Hence we see how very unfit some of the complicated forms shown in the old works on carpentry were for the purpose. It is certainly the height of absurdity to render the parts difficult to be fitted, when the whole of the strength depends on their fitting well. "But many," says Professor Robison, "seem to aim at making the beam stronger than if it were of one piece; and this inconsiderate project has given rise to many whimsical modes of tabling and scarfing."

Having already shown many varieties of scarfings under the general head of CARPENTRY, we shall here only point out the most approved forms for practical purposes, by way of illustrating the preceding observations.

Figure 1. Two pieces of timber connected by a single step on each piece. Here more than half the power is lost; neither is the scarf so capable of resisting the force of tension as a single piece of timber would be, were it sawed half through its thickness from the opposite side, at a distance equal to the length of the scarf: however, if assisted by straps, it may perhaps be capable of resisting a much greater force, particularly if each opposite surface be bolted on the sides of the transverse joints through the straps.

Figure 2. An oblique scarf, bolted in three places. Allowing the utmost cohesion of the part of the joint A B, to be the same as whole timber, and that the transverse parts, A D or B C, are one-fourth of the breadth, D E, the compound timber will possess three-fourths of the strength of a solid piece.

Figure 3. A scarf with parallel joints and a single table upon each piece. Here the cohesive strength is diminished in an additional degree to that of Figure 1, by the projection of the table; but this gives an opportunity of driving a wedge through the joint, between the ends of the tables and thereby forcing the abutting parts to a joint. This mode requires the scarf to be longer than those which have no tables; and the transverse parts of the scarf must also be strapped and bolted.

Figure 4. Allows of the same opportunity of wedging as before: if we would suppose the parts A B and C D to be compressed by bolts as firmly together as if they were but one piece they would be, by the continuity of the fibres, and if the projection of the tables be equal to the transverse parts of the joints at A and D; the loss of strength, compared with that of a solid piece, will be no more than what it would be at A and D.

Let it be here observed, once for all, that the strapping across the transverse part of the joint is the most effectual mode of preventing the pieces from being drawn from each other, by the sliding of the longitudinal parts of the scarf, and thereby giving the bolts an oblique position.

Figure 5. A scarf formed by several steps. In this, if all the transverse parts of the steps be equal, and the longitudinal parts as strongly compressed by bolts as the fibres of whole timber would adhere laterally, the loss of strength would only be a fourth, compared to that of a solid piece; there being four transverse parts, that is, the part which the end of a step is of the whole.

Figure 6. The end of each piece is formed by three steps, and the abutting parts of the middle step being greater than that at either extremity, the loss of strength in the compound timber is the part which the middle abutting surfaces are of the whole section.

Figure 7. A scarf consisting of six steps, the abutting parts being equal, and the longitudinal parts inclined in a small degree to the sides; so that when the two parts come to be bolted together, the pieces will dovetail each other, and thereby prevent their being drawn; but as all timber is liable to shrink in proportion to the dimensions of its section, no dependence can be put in dovetailing, for the shrinking may be so great, that the thickest parts of the solids at the abutment of the joint may pass through the narrower cavities, and render the dovetails useless. We may also observe, in the case of bolting, that when the longitudinal parts shrink from each other, the bolts will be drawn obliquely, unless the transverse parts on the sides be stripped and bolted, both opposite to the scarf and through the solid at each end of it. The strength of the compound beam may likewise be assisted by the iron; the dovetailing therefore can only give greater adhesion at first; at the same time, it occasions a small loss of strength, equal to the difference of the extreme end of the outer step and the nearer end of the whole section.

Figure 8. The method of forming a compound timber, when the two pieces are not of sufficient length to allow them to lap, by means of a third piece, connected with both by a double scarf, formed of several degrees, or steps; the pieces abutting upon each other, with the middle of the connecting piece over their abutment.

When girders are extended beyond a certain length, they bend under their own weight in the middle, and the degree of curvature will increase in a much greater degree than their lengths. An excellent method to prevent this sagging, without the assistance of uprights or posts from the ground or floor below, is, to make the beam in two equal lengths, and insert a truss, so that when the two pieces are bolted, the truss may be included between them, they forming its tie. To prevent any bad effects from shrinking, the truss-posts are generally constructed of iron, screwed and nutted at the ends; and to give a firmer abutment, the braces are let in with grooves into the side of each flitch. The abutments at the ends are also made of iron, and either screwed and nutted at each of the ends, and bolted through the thickness of both pieces, with a broad part in the middle, that the braces may abut upon the whole dimension of their section; or, the abutments are made in the form of an inverted wedge at the bottom, and rise cylindrically to the top, where they are screwed and nutted. These modes may be either constructed with one king-bolt in the middle, or with a truss-bolt at one-third of the length from each end. When there are two bolts, they include a straining place in the middle. The two braces may either be constructed of oak, or cast or wrought iron; the latter material is, however, very seldom employed. As wood contracts less in length than most metals, oak is better for the purpose than cast iron, but then the parts of the core must be so much stronger. As to the bolts, wrought iron is indispensable. It is obvious, that the higher the girder, the less will the parts be affected by the stress, and consequently there will be less risk of their giving way under heavy weights, or through long bearings.

Figure 9. A beam of two thicknesses bolted together, the scarfing of each length of timber alternating in the two thicknesses, so as to have the junction of two lengths in the one thickness opposite the centre of a length in the other thickness: the scarfing is similar to that of Figure 3.

Figure 10. A beam of three thicknesses bolted together, each thickness consisting of a number of short timbers so disposed, that the joints in no thickness come opposite the joints in either of the other thicknesses; a bolt occurs between every two joints.

Figure 11. A section of a girder with two braces and a king-bolt.

Figure 12. The section of a girder with a straining piece, two braces, and two truss-bolts, of the best principle. No. 1 represents the girder laid open, in order to show the core. No. 2, the two parts bolted together. No. 3, the edge of a washer. No. 4, the face of the same. No. 5, the side of the cut metal bolts, in the transverse direction of the girder. No. 6, the side of the same, in the longitudinal direction. No. 7, the transverse direction of the truss-bolt, or king-bolt.

Figure 13. The section of a girder, calculated from its rise to sustain very heavy weights. If the tie-beam be very strong, the abutments may be wedged; but then the wedges ought to be very long, the tapper very small, that there may be no inclination to rise. The excess of length may be cut off afterwards. The bolts represented at No. 5, and No. 6, Figure 12, are nevertheless to be preferred.

Two timbers may be joined, either by making both planes of contact parallel with or at right angles to the fibres, or by making the joint parallel with the fibres of the one piece, and at right or oblique angles to those of the other, or at oblique angles to the fibres of both pieces. When two pieces of timber are joined so that the common seam runs parallel with the fibres of both, the joint is called *a longitudinal joint;* but when the plane of the joint is at right angles to the fibres, it is *an abutting*, or *butt-joint;* this position brings the fibres of both pieces in the same straight line. If the joint be at right angles to the fibres of one piece, and parallel with those of the other, it is called *a square joint;* if the joint be parallel with the fibres of one piece and oblique to those of the other, it is *a bevel joint;* and lastly, if the joint be at oblique angles with the fibres of both pieces, the fibres forming an angle with each other double to that formed by the fibres of one piece and the joint, it is *a mitre joint.*

These are the general positions of simple joints in respect to the fibres of one or both pieces; those which may be compounded by the position of different planes, are of infinite variety, but as they seem to have little or no practical application, we shall not detain the reader longer on the subject. In fixing two pieces of timber together with longitudinal joints, the pieces are generally bolted, and sometimes pinned.

As to butting and mitre joints, they are seldom or never used in carpentry.

When two pieces of timber are joined together at one or more angles, the one piece will either meet the other and form one angle, or by crossing it form two angles; or the two timbers will cross each other, and form four angles.

In all the following cases of connecting two timbers, it is supposed that the sides of the pieces are parallel with the fibres, or, if the fibres be crooked, as nearly so as possible; and that each piece has at least one of its surfaces in the same plane with those of one of the other; the four sides being at right angles to each other.

The angle or angles so formed will either be right or obtuse. Notching is the most common and simple form, in permanent works, and in some cases the strongest, for joining two timbers at one or more angles, particularly when bolted at the joint. The form of the joint may be varied according to the position of the sides of the pieces, the number of angles, the quantity and direction of the stress on the one or both pieces, or any combination of these circumstances.

In the notching of timbers upon each other, the notch is generally supposed to be formed by planes, at right angles to, and parallel with the side in which the excavation is made; therefore the part of the corresponding piece must have its planes in a similar situation, the solid being contained between these planes, instead of the empty space, or notch, as in the

other. It may also here be remarked, that the notch is generally supposed to consist of three planes, unless it be otherwise specified.

Notching admits of the two pieces being joined at from one to four angles; but joining by mortise and tenon admits only from one to two angles.

In mortise and tenon joining, four sides of the mortise are always supposed to be at right angles to each other and to the surface whence it is recessed, and two of these sides to be parallel with each of the sides, which form a right angle with the side from which the mortise is made; the fifth plane, which is the bottom of the mortise, is parallel with the other. With respect to the tenon, four of its sides are parallel with the four sides of the piece.

In the application of timbers to buildings, it is here supposed that all pieces cut for use have a rectangular section, and when laid horizontally have their sides perpendicular to, and parallel with, the horizon.

If two pieces of timber are to be joined at four angles, cut a notch in one piece equal to the breadth of the other, so as to leave the remaining part of the thickness sufficiently strong, a very small excavation being sufficient; then insert the other piece in the notch: or if the work be required to be very firm, notch each piece reciprocally to each other's breadth, and fasten them together by pins, spikes, or bolts, as the case may require: this form is applicable where the pieces are equally exposed to a strain.

When one piece has to sustain another over it, transversely, and if only the upper be required to support a weight, cut a notch from its lower side, equal in breadth to about three-fourths of that of the lower piece, and as deep as the vertical distance that it is to be let down; then the lower piece must have a notch cut in its vertical side, leaving the middle of the upper face entire to three-quarters of its breadth, and the lower parts of the vertical side entire, so that the vertical depth of each notch may be the same as that of the upper notch: by this means the strength of the supporting or lower pieces is diminished in a much less degree than if the notch were cut out the whole breadth. This method is applicable to roofing and naked flooring.

The framing of timber by dovetail notching is chiefly applicable to horizontal framing, where the lower timber is sufficiently supported; but where the lower timber is unsupported, it is common to use mortise and tenon, which does not weaken the timber in any considerable degree; where the timber is notched from the upper side, the operation reduces its thickness, and consequently impairs its strength; though it may be said, if the solid of one piece fill the excavation of the other, and both be tightly driven or forced together (if we can place implicit confidence in the experiments of Du Hamel) and if the pieces be not cut more than one-third through, there will be rather an accession than a loss of strength. It may be observed, however, that in large works, where heavy timbers are employed, it is difficult, or almost impossible, to fit them with due accuracy; and even where the joints closely fitted at first, the shrinking would occasion cavities on the sides, that would render the tenons of no avail, because the axis of fracture would be nearer to the breaking, or under side of the supporting piece.

What has been observed with regard to horizontal pieces of timber, applies to framing in every position, where the force is to fall on the plane of the sides; and if a number of pieces thus liable to lateral pressure on either side, are to be framed into two other stiff pieces, the mortise and tenon will prove best for the purpose.

When joists are framed into trimmers, the usual method is to make the mortise on the tenon with a plain shoulder, in the middle of the sides of its respective timber: this mode is particularly used in letting down bridging joists upon binding joists, and small rafters upon purlins.

If it be required to join two pieces of timber, to form two right angles, so as to be immovable when the transverse is held or fixed fast, and the standing piece pulled in a direction of its length; cut a dovetail notch across the breadth of the transverse piece, and notch out the vertical sides of the standing piece at the end, so as to form a corresponding similar and equal solid. In some pieces of work, besides the dovetail, an additional notch is cut, to receive the shoulder of the lower piece. If the position of these pieces be horizontal, and the upper of sufficient weight, or pressed down by any considerable force, when the pieces are put together in their place, the dovetail will be sufficiently strong without the assistance of pins, spikes, or bolts. This construction requires the timbers to be well seasoned, for otherwise the shrinking will permit the standing piece to be drawn out of the transverse, and thus defeat the purpose which the construction was intended to answer. The following method of remedying this defect will be found effectual:—Cut the transverse piece in two excavations from the upper side, so that if the breadth be supposed to be divided into five equal parts, and a notch equal in breadth to three parts be cut next to the outer vertical side, and the other notch be made equal to the breadth of one part, and each notch depressed from the upper face about one-third the thickness of the piece, so as to leave the second part on the upper surface next to the inner vertical side, and the two-thirds of the depth of each vertical side next to the lower side entire: then the corresponding single notch being made on the standing piece to the solid left on the upper surface of the transverse piece, the two pieces will reciprocally receive each other.

When binding joints are framed into girders, as they have to support the bridging joists and boarding of the floor, there will be a considerable strain at their extremities; in order to make the tenons sufficiently strong to resist the weight, they should be framed with a shorter bearing tenon attached to the principal tenon and a sloping shoulder above, called *a tusk;* tenons thus formed are called *tusk tenons.*

When two parallel pieces, quite immovable, are to have another piece framed between them, proceed thus:—Insert the one end of the tenon of the connecting piece into a shallow mortise, and make a long mortise in the opposite side of the other timber, so that when the cross piece is moved round the shoulder of the other extremity, as a centre, it may slide home to its situation: thus if the tenon at the movable end fit the mortise closely, the bottom of the mortise would be the arc of a circle, of which the shoulder of the tenon first formed would be the centre: but the bottom of the long mortise may be straight instead of circular, provided it be sufficiently recessed to clear the end of the piece. This mode of framing a transverse piece between two others is employed in trimming in ceiling joists: the binding joists are always previously mortised before they are disposed in a situation to receive them, and the ceiling joists are seldom or never cut to their lengths and fitted in before the building is covered over.

When a transverse piece of timber is to be framed between two parallel joists, of which the vertical surfaces are not parallel, turn the upper edge of the transverse piece downwards upon the upper horizontal surface of the joists; mark the interval or distance between them upon the surface of the transverse piece now under; then turn the transverse piece in the way it is intended to be framed, placing the edge over the places where it is to be let down; then apply a straight-edge to the oblique surface of the joist, and slide

the transverse piece so as to bring the mark upon the upper side of it in a line with the straight-edge. This being done, proceed in the same manner with the other end, and the two lines drawn on the vertical sides of the intermediate piece will mark the shoulders of the tenons. This process is called by workmen *tumbling-in joists*, and is particularly useful when the timber is warped or twisted.

Having shown the principles of lengthening timber and strengthening of beams, also the methods of joining timbers at angles, we shall now proceed to construction in general.

In groin centering, the boarding which forms the exterior surface for building upon is supported by transverse ribs of timber, which are either constructed simply, or with trusses, according to the magnitude of the work; and as a groin consists generally of two vaults crossing each other, one of them is always boarded over, the same as a plain vault, without having any respect to the other, which is afterwards ribbed and boarded, so as to make out the regular surface.

Timbers disposed in walls and at returns or angles, are joined together where the magnitude of the building, or exposure to strain, may require. These are of three denominations, as bond-timber, lintels, and wall-plates.

Flooring is supported by one or more rows of parallel beams, called *naked* or *carcase-flooring*, and is denominated either *single* or *double*, accordingly. The manner of joining the timbers we have already spoken of.

During the construction of the building, the flooring of carpentry, if not supported by brick or stone partitions, is either supported by the partitioning of timber or by shores. The construction of the flooring, whether single or double, depends upon the magnitude of the building, the horizontal dimensions of the apartments, or the weight which the boarding may be required to support. When the flooring is required to be very stiff, it becomes necessary to use truss girders.

Naked flooring for dancing upon should be made very strong, and so contrived that the upper part of it may spring, so as to bend to the impression of the force, while the lower part, sustaining the ceiling, remains immovable.

Partitions are constructed of a row of timbers, or if the length of the bearing require very great stiffness, they are made of framed truss-work, and afterwards filled in with parallel timbers. The trussing of partitions may be made to assist in giving support to the floors, where they are unsupported below. The framing ought to be so managed as to discharge the office of hanging up the floor, in whatever situation the doors are placed. Truss partitions are also of the utmost use in supporting the superior floor.

The covering of the roof is sustained by one or several rows of parallel timbers, each row being in a plane parallel to the covering. The force of the timbers, which would act laterally upon the walls, is generally restrained by tie-beams placed upon wall-plates on the top of the walls, and fixed to the lower ends of the rafters. In roofing, many ingenious contrivances may be resorted to, their application depending upon the pitch of the roof, the number of compartments into which it may be divided, or whether there are to be tie-beams or not. If an apartment is required to be coved into the roof, a longitudinal truss, supported at the ends, may be placed in a vertical plane under the ridge, by which the rafters may be hung; for it is evident, that if the upper ends of the rafters were held in their situation, their lower ends would descend by their gravity, and would describe arcs of circles in vertical planes, and in their descent would approach nearer together, and, consequently, instead of pushing out the walls, would have a tendency to draw them towards each other, And if beams were placed transversely immediately under the longitudinal truss, and fixed to the opposite rafters, they would act as straining pieces, and prevent the exterior sides of the roof from getting hollow. If the whole space within, under the rafters, were required, that is, to have no intermediate work of trussing, the sides of the roof may be prevented from descending by arching them with cast iron, or trussing them with wood in the inclined planes of their sides; and to restrain the pressure of the rafters, which would be discharged at the extremities of the building, a strong wall-plate, well connected in all its parts, must be introduced, which, acting as a tie, would prevent the lateral pressure forcing out the walls.

In this construction, as well as in the former, the rafters would have a tendency, from their gravity, to become hollow; in this case straining beams should be introduced at a convenient height, which would have a good effect in counteracting that tendency. If it be required to occupy very little space by the wood-work, cast-iron arches, abutting upon each other, and screwed with their planes upon the upper sides of the rafters, will answer the purpose best.

The idea of trussing roofs upon these principles was discovered, many years ago, by Mr. P. Nicholson, in consequence of a dispute concerning a roof which had been constructed upon a chapel, and which had pushed out the walls to such an alarming degree as to threaten the demolition of the whole fabric: Mr. Nicholson was chosen as arbiter, but the principle which the architect adopted was so incompatible with the nature of the design, that, though chosen by the architect himself, he was under the disagreeable necessity of giving judgment in favour of the constructor. This roof was truncated, or flat, and the ceiling within cylindrical, extending horizontally the whole clear of the walls, and in height to the under sides of the camber-beams, so that there were no ties between opposite rafters. The principle consisted, therefore, of two sloping sides and a camber-beam, which were only tied together by angle-braces, and as the ceiling came in contact with the under side of the rafters and the under sides of the camber-beams, the braces were also disposed so that the middle of their under sides came in contact with the ceiling, and thus, to maintain the roof in its position, depended entirely upon the resistance of the walls, or upon the inflexibility of the timbers, or both; all of which were of unusual strength.

The lesson which every architect ought to learn from this, is, always to construct his roof in such a manner as to make it entirely dependent on itself.

In the year 1802, two years subsequent to the above dispute, a model of a roof was exhibited before a numerous meeting of the Philosophical Society at Glasgow, wherein the timbers consisted simply of rafters abutting at the top upon a ridge-piece, leaving the whole space under the rafters clear, and, of course, forming a triangular hollow prism, with the two upper sides parallel to the inclined planes of the exterior. The wall-plates were unsupported, except at the four corners, which were sustained by uprights or posts; the pieces let in upon the upper sides of the rafters consisted of small arcs, almost straight, forming on each inclined plane a parabolic curve, and extending from post to post. From the ridge-piece equal and very considerable weights were suspended, one from the meeting of every pair of rafters, without producing any visible effect upon the wall-plates.

The form of a parabolic curve is best adapted to that of equal weights suspended at equal distances. Instead of arcs, simple trusses may be used, and the rafters may bridge over them.

In many cases, where space is required, we cannot help thinking, that the disposition and fixing of the boarding in

the form of a truss, is vastly superior to placing them with their joints parallel to the horizon, and would be a very proper substitute for arching or trussing the sides in all roofs of moderate dimensions. It must, however, be observed, that the meeting of every two boards ought to be as nearly as possible upon the middle of a rafter, and not over the hollow. To which we may add, that as all the joists are abutting in such disposition, the boards forming trussed work may be made thicker, and let into the rafters, which will give greater security to the abutments; but for this purpose they ought to be firmly fixed at their meeting, to prevent them from starting.

The principle of arching the inclined sides of a roof, and making the wall-plates act as ties, is exhibited in the architectural plates of Rees' *Cyclopedia*, published in 1805.

Circular roofs may be executed without ties, or without any precaution of trussing, as in rectangular buildings, but the wall-plate ought to be one continued mass. There are two methods of covering circular roofs with boards: one is, to bend the boards with their joints in horizontal planes; and the other is, to bend them in planes passing through the axis. As that species of circular roofs called *domes* lays considerable claim to our attention, it will here be proper to say something on their construction.

If the dome be spherical, and have no lantern to support, the ribs may be constructed of boards in two or three thicknesses, with the longitudinal joints of the boards tending to the axis of the dome, and intersecting the spherical edges, and the butting joints intersecting the sides of the ribs, which tend to the said axis.

Let us now suppose the thickness of a rib to consist of three boards, and suppose the circular pieces which are to compose the ribs, to be all prepared of equal lengths and breadths. Take one of the lengths, suppose for the left-hand piece at the bottom, and lap the next higher length, which is the middle piece, two-thirds upon the lower piece; take another length for the right-hand piece, next higher, and lap this two-thirds on the middle piece; so that the right-hand piece will lap one-third upon the left-hand piece; between the ends of this third, bolt or pin the three pieces together; the middle board will want a third, the right-hand board two-thirds, to make it complete at the bottom; these parts being supplied and fixed, lay another board at the higher end of the right-hand board, the end of another to abut upon the higher end of the middle board, and the end of a third board to abut upon the upper end of the left-hand board, then there will be three piles of boards, which must be fastened together between each pair of heading joints, which are three in number. Proceed in like manner with every succeeding three boards, as with the last three, until you arrive at the top, and the deficiency must be supplied as at the bottom. In this manner, every rib in succession must be constructed, until they are all finished. Each rib ought to be fitted to the curvature of the axal section of the dome, drawn on a floor, and the three thicknesses fixed together throughout the whole length, before it is removed. If, in addition to the fixing, the joints be strapped, it will add considerably to the strength, and will not be much inferior to that of a solid piece. In large domes of this construction, it becomes necessary to discontinue the ribs, otherwise an unnecessary quantity of timber would be employed; and it must be observed, that the greatest intervals must be so regulated in their dimensions, as not to be greater than what would make the horizontal ribs for the boarding, when fixed, sufficiently strong.

As all domes are best boarded with their joints in vertical planes tending to the axis, horizontal pieces must, in this case, be strutted between the ribs, and their outer sides formed with the spherical surface. A dome constructed in this manner, might also be made to support a heavy lantern, provided the strutting-pieces were strapped together. In the above manner was the timber dome of the Halle du Bled, at Paris, constructed by Moulineau, supposed to be the first of the kind.

If the boarding of the dome is required to be bent, with the joints in horizontal planes, and the dome have no lantern, a very good method is, to construct it with several vertical ribs, their planes being disposed at equal angles round the axis as their common vertex, and constructed according to the above method; between every pair of such ribs, place other ribs, the curvature of which will be portions of less circles of the sphere, unless one stand in each interval, and its plane bisect the inclination of the vertical planes of the two adjacent principal ribs: dispose of these ribs in equidistant parallel planes, and fit their upper ends upon the sides of the principal ribs. This disposition of the ribs will be a considerable saving of timber, besides what it would have been, had the planes of all the ribs tended to the axis.

In the construction of plaster groins, two methods are employed in the disposition and fixing of the ribs. By both methods, ribs are made to answer the intersections at the angles: by one method, ribs are formed to the transverse sections of the vault, and disposed in vertical planes accordingly; but by the other, the ribs are prepared straight, and fixed parallel to the axis of each vault.

The lathing for plaster is sustained upon walls, by a number of parallel posts of very small scantlings, called *battening*, and ranged according to the figure they are intended to form.

CONTABULATE, to floor with boards.

CONTACT (from the Latin, *contactus*, touch) the mutual touching, or meeting, of two things.

Contact, in geometry, is when a line or plane meets a figure or solid, without cutting it, though the line or plane be produced. Thus, a line and a circle are in contact when the line is a tangent to the circle; and two circles are in mutual contact, when they touch each other without cutting: the like is to be understood of a plane and a convex body, as a cylinder, cone, conoid, &c.

CONTENT (from the Latin, *contentus*) that which is contained, the thing held, included, or comprehended within a limit or line. In geometry, the area or quantity of matter or space included in certain lines. *Linear content*, length simply; *superficial* content, area or surface; *solid* content, the number of cubic inches, feet, yards, &c. contained in a given space.

CONTEXTURE (from the Latin, *contexo*, woven) the disposition or union of the constituent parts of a body in respect of each other.

CONTIGNATION (from the Latin, *contignatio*, *con* and *tignum*, a beam), a frame of beams, in ancient Roman carpentry, the same as we now understand by *naked flooring*.

CONTIGUITY (from the Latin, *contiguus*, to meet) the relation of surfaces or solids whereby their sides join each other.

CONTIGUOUS ANGLES, in geometry. *See* Angles.

CONTINUED, a term applied to whatever is not interrupted, but proceeds in the same course.

Continued Attic, an attic not broken into pilasters.

Continued Pedestal, a pedestal with its mouldings and dado, or die, continued both through the column and intercolumn, without being broken.

Continued Proportion, is when there is a series of lines or quantities, such that the first is to the second as the second

is to the third, and the second to the third as the third to the fourth, and so on.

CONTINUED SOCLE, the same as *a continued plinth.* *See* PLINTH.

CONTINUOUS BEARINGS, balks of timber laid under the rails of a railway for their support, in place of stone sleepers, or blocks fixed at certain intervals. These balks, or longitudinal sleepers, as they are generally termed, are secured to cross transoms fixed to piles.

CONTINUOUS IMPOST, in mediæval architecture, the mouldings of an arch carried down to the ground without interruption, or anything to mark the impost-point.

CONTORTED, wreathed. *See* WREATHED.

CONTOUR (from the French; synonymous with *contorno*, Italian) the outline of a body; to have which correct, is one of the greatest requisites in drawing and painting.

CONTRAMURE. *See* COUNTERMURE.

CONTRAMURE (from the French, *contre*, against, and *mur*, a wall) in fortification, an external wall built about the walls of a city.

CONTRARY FLEXURE, *Point of*, or POINT OF RETROGRESSION, the point in which two curves meet that have the convexity of the one and the concavity of the other on the same side of the line.

CONTRAST (from the French, *contraste*) to avoid the repetition of the same thing, by introducing variety; as is done in antique edifices, where rectangular and cylindrical niches with spherical heads are alternately introduced; also, in the dressings of niches, as in the Pantheon, tabernacles are introduced with circular and triangular pediments alternately.

CONTRAVALLATION, (in fortification), a trench guarded with a parapet, thrown round a besieged place by the besiegers, to protect themselves, and check sallies of the garrison.

CONVENIENCE (from the Latin, *convenientia*) an easy or accessible distribution of apartments in respect to the intention of the design.

CONVENT (from the Latin, *conventus*, an assembly). *See* MONASTERY.

CONVENT, a religious edifice, in which lived assemblies of persons devoted to a religious life, under the authority of a superior. Convents for males are termed monasteries, those for females, nunneries; when under the jurisdiction of an abbot, or abbess, they are named abbeys, and under that of a prior, or prioress, priories.

CONVENTUAL CHURCH, a church belonging to a convent, and consisting of regular clerks, professing some order of religion, or of a dean and chapter, or other societies of spiritual men.

CONVERGENT CURVE. *See* CURVE.

CONVERGENT LINES, such lines as if produced would meet.

CONVEX LINE, that side of a curve which has no contrary flexure, and on which a tangent may by drawn.

CONVEX RECTILINEAR SURFACE, a curved surface, such, that if any point be taken, a straight line passing through the point can only be drawn in one direction, and if another point be taken out of the straight line so drawn, another straight line passing through this and the former point, will pass within the solid. Bodies having this property are cones, cylinders, and many others.

CONVEX SURFACE OF A SOLID, a curved surface, in which, if any two points be taken, the straight line joining them will pass through the body: all the solids generated by the revolutions of conic sections, except the triangle, have this property.

CONVEXITY (from the Latin, *convexus*) the same as *convex surface.*

CONVOLUTION (from the Latin, *convolutio*) a winding or turning motion.

COOPER (from the Dutch, *kype*, a barrel) a person whose business it is to make vessels of wooden boards, hooped together around a circular or elliptic circumference.

COOPERY, the art of making vessels of boards, by joining them edge to edge, and binding them round the exterior sides with hoops, so as to form a hollow body of circular or elliptic sections, and so as to contain a liquid, with one or two ends.

The boards of which vessels are made, are called, in the rough state, *clap-boards;* but when wrought up in the vessels, they are called *staves.*

The art of coopery is a curious branch of mechanism; it requires a knowledge of geometry, as well as of the covering of solids, to be able to construct a vessel or cask of a rotative figure, agreeably to a given section through the axis; the edges of the staves require to be of a particular curvature, so that, when joined together, they may form the required contour of the vessel. This, though not a branch of architecture, is founded upon the same common principles.

CO-ORDINATE (from the Latin, *con*, with, and *ordinatus*, order) a term expressive of two objects holding the same rank.

CO-ORDINATE PILLARS, such pillars as stand in equal order.

COPED TOMB, one which has its top or covering sloping down towards both sides.

COPESTONE, head or top-stone.

COPING (from the Dutch, *kop*, the head) in masonry, the stones laid on the top of a wall, to strengthen and defend it from the injuries of the weather.

COPING of equal thickness, is called *parallel coping*, and is only used upon inclined surfaces, as on a gable end, or in situations sheltered from the rain; as on the top of a level wall intended to be covered by the roof.

COPING thinner on one edge than on the other, for throwing off the water on one side of the wall, is called *feather edged coping.*

COPING thick in the middle and thin at each edge, whether the back be formed of two planes meeting in an angle over the middle of the wall, or whether forming the arch of a circle in its transverse section, is called *saddle-backed coping.* This kind of coping throws the water on both sides, and may be used over the walls of sunk areas, or of a dwarf wall, which is to have an iron-railing, and in the best-constructed fence-walls.

COPING upon the gable end of a house, is called *factabling* in Liverpool.

COPING, in the pointed styles of architecture, is either inclined upon the faces, or plumb. When inclined upon the faces, the sides of the vertical section are the sides of an equilateral triangle, whose base is horizontal. This sort of coping is sometimes in one inclined plane, terminated with an astragal at the top, while at the bottom it changes its direction into a narrow vertical plane, which projects with a level soffit before the parapet. Sometimes it is in two inclined planes, parallel to each other, the upper terminated with an astragal at the summit, and projecting before the lower, and the lower before the vertical face of the wall, in the same manner as that which has only one inclined plane. This coping is used in plain parapets, or in battlements. When used in battlements, it is either returned on the vertical sides of the embrasures or notches, or only crowns the top of the ascendants, and bottom of the notches.

The coping of battlements with vertical faces, has a small

projection beyond the face of the wall, and the coping is returned on the sides of the notches.

Inclined coping is sometimes made without the astragal at the top, and the soffit before the vertical face of the parapet perpendicular to the inclined face of the coping.

Coping over, is said of the soffit of a projecture from the naked of a wall, when the soffit is inclined so as to make an acute angle with the vertical face of the wall below it; that is, when the edge of the soffit in the surface of the wall, or next to it, is higher than the outer edge.

CORBEILS (from the Latin, *corbis*, a basket) a piece of carved work, representing baskets filled with flowers or fruit, to finish some ornament.

CORBEL, a term used by some for a niche or hollow in a wall, to contain a statue, bust, &c.

Corbel, a block of stone or other material projecting from the face of a wall, and used to support a superincumbent weight, such as the beams of a roof, ribs of vaulting, columns, and such like. The term is confined chiefly to such supports employed in Gothic architecture, in the buildings of which styles corbels occur very frequently; they perform somewhat of a similar office to the modillions or consoles used in Classical buildings, but their more perfect prototype is to be seen in the projecting figures and heads supporting consoles, in the remains of the baths of Dioclesian, at Rome.

Corbels are usually carved in grotesque heads, animals, flowers, &c.; in the Romanesque style they are either simple square blocks with the face occasionally rounded, or carved in the shape of grotesque heads; in the Early-pointed, the corbels are sometimes moulded, and in the richer specimens carved into knops of foliage; when heads or masks are used, they are not of such grotesque appearance as during the preceding period; in the next style they are more frequently foliaged, and in the Perpendicular carved in the form of angels sometimes bearing shields and other devices; in the later styles, the corbel is usually terminated above by a moulding, or series of mouldings, forming a kind of capital. Corbels of large dimensions, such as those supporting a group of clustered columns, are generally very elaborately ornamented in combinations of masses, or groups of foliage springing from one or more points underneath, and clustered together under the cap; sometimes groups of figures are introduced, as in the beautiful specimens to be seen in Exeter Cathedral.

Corbels are not unfrequent in castellated architecture, and when so employed are of a very massive character. They have usually two of their sides vertical planes, perpendicular to the surface or face of the wall; and their other surfaces, which are their edges or fronts, quarters of cylindroids, with the greater axis of their section perpendicular.

The edge of each corbel generally consists of one, two, and sometimes three convex rectilinear surfaces: when the edge of each bracket consists of two or three convex rectilinear surfaces, these surfaces are generally separated by fillets, which have vertical sides parallel to the face of the building, and horizontal soffits.

Corbels are also a horizontal row of stones or timber, fixed in a wall, or in the side of a vault, for sustaining the timbers of a floor, or those of a roof. Many of the timber floors, or contignations, in old buildings, were thus supported; the timbers of the domic roof of St. Paul's are tied to the conic vault by means of corbels. The ends of the corbels are generally cut into a convex or ogee form.

Corbels, in the Caryatic order, are those parts upon the heads of the Caryatides, under the soffit of the architrave cornice, that represent baskets, or rather cushions, and have an abacus, as in the Grecian orders.

The term is also used for the vase of the Corinthian capital, it being in form of a basket.

Corbel-Bole, a moulding, in Norman architecture, employed frequently to support a blocking course. It consists of two rows of billets or cubical blocks of stone disposed at intervals, and so arranged, that the blocks alternate in the two rows, a block coming under a space, and *vice versa*. *See* Billet-Moulding.

Corbel-Steps, sometimes called *corbie*-steps, a term applied to steps up the sides of a gable; when the parapet is formed into a kind of battlement, broken into steps or ledges, which converge from the eaves to the apex. Specimens are to be seen in many old houses, especially in Scotland, Flanders, Holland, and Germany. They may have been used perhaps for extinguishing fire, or escaping from it, or merely for ornament.

Corbel-Table, a series of corbels disposed at regular intervals projecting from a wall, to support a parapet or other continuous projection, and frequently seen under the eaves of a roof. The corbels are occasionally plain, but often carved in the shape of grotesque heads, and other devices, as above-mentioned. Sometimes the corbels are connected by small arches which intervene between them and the superstructure, and form its immediate support; these arches vary in shape, according to the style of architecture of the building in which they are employed, as do also the corbels; in the Romanesque structures they are circular, during the next period intersecting, and lastly, pointed and trefoiled. Corbel-tables were more frequent in the Romanesque styles than in any others, in which they form a bold and effective feature. They are found in a peculiar situation in many Lombardic structures, running up the raking sides of the wall beneath the gable; a singular instance of this position is to be seen in the west gable of Adel Church, Yorkshire.

CORBETT, a word used by Harris, in his *Lexicon*, for a corbel. Corbetts, niches for images.

CORBETTIS, a word used by Chaucer, for stones upon which images stand.

CORBS, a Spanish word for architectural ornaments.

CORD, in geometry. *See* Chord.

CORDON, the edge of a stone on the outside of a building.

CORE, the interior part of anything. Every masonic wall should have thorough-stones at regular intervals, in order to strengthen the core, which is generally made of rubble-stones: or, otherwise, when thorough-stones are only to be had with difficulty, two bond-stones lapped upon each other, one from each face of the wall, may be used: or, instead of each thorough-stone lay two stones level on the upper bed, and one large stone in the core, lapped upon both, observing that the tails of the two lower stones be right-angled; by this means the two sides of the wall will be completely tied together.

CORICEUM (from κωρικειον) in Grecian antiquity, the undressing-room belonging to the Gymnasium.

CORINTHIAN ORDER, the third of the orders of Classical architecture, and the first of the foliaged, under which title we include the Corinthian and Composite. These two orders might conveniently be classified together, and reasonably too, if we consider their general resemblance, and also that some examples of the former class differ as much from that which is considered their most perfect type or model, as do those which are included under the Composite or Roman order; if both styles were comprised under one division, it would form a very distinct and marked style, which might be entitled the Roman or Foliaged order.

How this particular class of examples obtained the appella-

tion of Corinthian, is not very readily accounted for; one would naturally suppose this name was assigned on account of the origin of the style, or the prevalence of examples in Corinth or its neighbourhood, but such is by no means the case. In the first place, the origin has never been attributed to that locality by any author except Vitruvius, and even if we give credit to his account, the merit of the first idea ought in fairness to be given to the Athenians; but at best the story told by this author rests on a very insecure foundation, as we shall presently attempt to show. No other writer has alluded to any buildings of this order as existing at Corinth; and if the style ever did prevail in that city, we have now not a single example remaining to testify to the fact.

Vitruvius's account of the invention of the capital, is as follows:—Callimachus, an Athenian sculptor, passing the tomb of a young lady, observed an acanthus growing round the sides of a basket, covered with a tile, and placed upon the tomb, and seeing that the tops of the leaves were bent downwards, in the form of volutes, by the resistance of the tile, he took the hint, and executed some columns with foliated capitals, near Corinth, of a more slender proportion than those of the Ionic, imitative of the figure and delicacy of virgins.

This story, though bearing no marks of improbability in itself, when compared with facts, loses a considerable amount of its credibility, and stands upon the same level as the other fanciful tales related by the same author. As regards the one more immediately before us, it need only be remarked, that the earliest specimens of this order have but little in agreement with the idea which one would suppose to have presented itself to the mind of an artist under the circumstances related; the foilage of what seems to be the earliest specimen extant, does not consist of acanthus leaves at all, but of what have from their shape been termed water-leaves; it is in the Roman examples we see the best illustration of the basket and acanthus; in short, the earlier the example, the less the resemblance, a fact which throws discredit upon the whole story, and would lead us to believe that the latter was invented by Vitruvius, not the order by Callimachus. Moreover, there is reason to doubt of the antiquity of the order being so great as Vitruvius would have us believe; for Callimachus flourished about the 60th Olympiad, or 540 years before the Christian æra. We are informed by Pausanias, lib. viii., that the ancient temple of Minerva, at Tegæa, in Arcadia, having been destroyed, a second edifice was erected, under the direction of Scopas, far exceeding in splendour and magnificence every building of the kind in the Peloponnesus. In this structure, all the three Grecian orders were employed; the outside was embellished with colonnades of the Ionic order; and the hypæthral area of the interior was surrounded with porticos and galleries above, formed by the Doric and Corinthian orders. This æra of building may be placed in the fourth century before Christ, and is the first in which a distinct account of the Corinthian order being introduced in any regular building, is to be found. It was not in general request till the third age of Rome, under the emperors. The examples which are to be found in Greece, are but few, and some of them seem of a date posterior to the period of the Romans getting possession of that country; such as the temple of Jupiter Olympius at Athens.

Most modern writers are of opinion that the Corinthian capital was invented by the Egyptians, and with good reason; yet, although many bell-formed capitals are to be found among the ruins of Egypt, the taste, the delicacy of the foliage, the beautiful form and elegance of the leaves, caulicoli, and volutes, with the symmetrical and easy disposition of the whole, are superior to anything yet discovered among the Egyptian ruins; and even in the present day, this capital exhibits the utmost elegance, beauty, and richness, that have ever been attained in architectural composition, though many attempts have been made to exceed it.

Some writers suppose that the Corinthian arose naturally out of the Doric order, and cite in favour of their hypothesis, the absence of bases, the simple capital, and the square abacus, in the Tower of the Winds, the use of mutules in the shape of modillions, and such like; but we think those who maintain its Egyptian origin, have the better evidence on their side.

The Corinthian order, like the other two, after being introduced, continued to be the fashionable order in Greece, Italy, and Asia; and was the only order well understood, and happily executed, by the Romans. Among the superb ruins of Balbec and Palmyra, excepting the lower Ionic order in the circular temple, and a Doric column at the former place, it is, we believe, the only order to be found.

Vitruvius says, the shafts of Corinthian columns have the same symmetry as the Ionic, and that the difference between the entire columns arises only from that of the heights of their capitals; the Ionic being one-third, and the Corinthian the whole diameter of the shaft, which, therefore, makes the height of the Corinthian two-thirds of a diameter more than that of the Ionic: hence, as he has allowed the Ionic to be eight diameters, the Corinthian will be eight and two-thirds.

The average height of the column, inclusive of capital and base, taking a mean proportional between those of the Pantheon and of the temple of Jupiter Stator, is ten diameters, the shaft containing eight, and the remainder made up in the capital and base.

The shaft in the ancient examples was almost invariably fluted, and the flutes occasionally filled to about one-third of their height with cabling; the number of the flutes is generally twenty-four, the same number as in the Ionic order, and arranged in the same manner, having a fillet between every two channels. The only ancient examples in which the flutes were omitted, were cases in which the shafts were composed of polished granite or some variegated marble, in which there was sufficient richness and play of colour, without further decoration.

The capital is separated from the shaft by an astragal and cincture, or fillet, and is in the shape of an inverted bell, the ornamentation of which may be described as follows: Immediately above the astragal, are two rows of acanthus or olive leaves one above the other, each row consisting of eight leaves; the upper row is arranged in such a manner as to have one leaf immediately in the centre of each side of and beneath the abacus, and one other under each corner of the abacus, which altogether, one in the centre of each side, and one at each angle of the capital, will make up the eight leaves. The leaves of the lower range are disposed so as to alternate with those of the upper; that is to say, the spaces left between the lower leaves are occupied by the lower portions or stalks of the upper leaves, or, in other words, the upper leaves rise between the divisions of the lower ones. Between every two of the leaves of the upper or second series, rises a stalk, out of which springs a bunch of foliage, consisting of two leaves, one of which branches towards the centre of the abacus, and the other towards the angle. We have therefore eight of these stalks, termed *caulicoles*, each giving out two branches or leaves, of which therefore there are sixteen, and if we consider their direction as above described, we shall find that we have two of them tending to meet at each angle, one from each contiguous side of the capital, and two likewise tending towards the centre of each side above the central leaf of the second range. Out of each of the leaves at the angles,

proceeds in a diagonal line, a spiral horn or volute, the two at each angle meeting under the abacus, which they support; two similar though smaller ones emerging from the central leaves, meet under the centre of the abacus, and are surmounted by a small flower, called the flower of the capital.

The abacus is square in its general plan, or rather is of such form as may be inscribed in a square; the sides are concave, curving out towards the angles, but the points which would be formed by the intersection of the curves, are most usually cut off; sometimes the corners are pointed, but rarely. This shape of the abacus arises out of the form of the capital, which recedes in the centre of each side, and projects at the angles; the abacus does not overhang the capital. The mouldings consist of a cavetto, fillet, and echinus, the first and last of which are sometimes enriched.

The proper Corinthian base differs from the Ionic or Attic, in having two smaller scotiæ separated by two astragals; both bases, however, are used indiscriminately, and perhaps the Attic is more generally employed—it was preferred both by Palladio and Scamozzi.

The above may be considered as a description of the standard form, for the details of the order vary to a very considerable extent in the different examples, to such an extent, indeed, that there are scarcely two ancient examples alike. The ornamentation of the capital differs very greatly in the Greek and Roman examples; in the former, the leaves have angular points, and are almost straight on the sides, while in the latter they are altogether of a more rounded form, in fact the Greek leaves were more harsh and stiff, and have the natural character of the acanthus, whereas the Roman are more artificial. In the Temple of the Winds, which is a very early, if not the earliest specimen remaining, the upper row of leaves, if it may be said to have more than one row, is merely carved upon the vase, and consists of broad flat leaves, which have been named from their appearance, water-leaves; there are no volutes, and in consequence the abacus is not curved, but is merely a square block; add to this the absence of a base, and you will perceive at once that this specimen disagrees almost entirely from the description above given. In the temple of Vesta at Rome, which is probably copied from that at Jackly near Mylasa, the lower range of leaves, instead of following the line of the shaft as usual, project beyond it. The monument of Lysicrates is a beautiful though small specimen, and differs materially from any of the above; in short, every example, whether Greek or Roman, has its peculiarity.

The height of the abacus is one-seventh, the lower and upper tier of leaves each two-sevenths; and the caulicoli and volutes, which spring from the stalks between every two leaves in the upper row, the remaining two-sevenths of the diameter: the breadth of the capital at the bottom is one, and each diagonal of the abacus two diameters of the column.

Vitruvius makes no mention of obtunding the corners of the abacus, as is generally practised by the ancients as well as the moderns: we are therefore led to suppose, that each pair of the four faces of the abacus were continued till they met in an acute angle at each corner, as in the temple of Vesta, at Rome, and in the Stoa, or Portico, at Athens. The division of the capital is the same as is frequently used by the moderns; but the entire height is generally made one-sixth more than the diameter of the column, while that of the column is ten diameters.

This order does not appear to have had any appropriate entablature in the time of Vitruvius; for, in book iii. chap. i. he informs us, that both Doric and Ionic entablatures were supported by Corinthian columns; whence it appears that the columns constituted the order, and not the entablature. "The Corinthian," says he, "has no cornice, or other ornaments peculiar to itself, but has either triglyphs, mutules in the cornice, and guttæ in the epistylium, as in the Doric order; or otherwise, the zophoras is ornamented, and dentils are disposed in the cornice, as in the Ionic."

This observation of Vitruvius regarding the use of the Doric entablature, is no less extraordinary in itself than that it is unsupported by any ancient examples; but his remark, concerning the Ionic, is verified in many instances; as in the temple at Jackly near Mylasa, the temple of Vesta near Tivoli, and that of Antoninus and Faustina at Rome; the arch of Adrian at Athens, the Incantada at Salonica, and the portico of Septimius Severus at Rome. However, in the remains of antiquity, we more generally find Corinthian columns supporting an entablature of a peculiar species. This consists of architrave, frieze, and cornice, the first of which is divided into three faces, the lowest one much narrower than the upper two, with mouldings between each; the upper surmounted by an astragal, ogee, and fillet, the middle by a small ogee, and the lower by a bead; these mouldings were frequently plain, but sometimes enriched, more especially the two last mentioned. The frieze was sometimes plain, sometimes enriched with sculptured figures, foliage, or other ornamentation. The most striking peculiarities are to be observed in the cornice, which consists of the denticulated band of the Ionic, supported by an ogee and astragal enriched, and surmounted by an enriched astragal and echinus; over these are the mutules of the Doric, but their proportion is changed, and their figure converted into a console, which shows upon the ends and sides of each, the bottom being covered with a foliated leaf. The consoles in this application, are called *modillions*, and support the corona which consists of the same mouldings as the Ionic, with occasionally a greater amount of enrichment; the cymatium is often decorated with lions' heads, to serve as spouts or gurgoyles. This entablature does not appear to have been in use in the time of Vitruvius, since he takes no notice of it; though very particular in many other points less worthy of attention. The cornice here specified, is not only to be found in most of the ancient buildings of Italy, but is observed in all the celebrated works of Balbec and Palmyra.

Thus the Romans, and other contemporary nations, affected to give the Corinthian order an appropriate entablature, though the Ionic was sometimes employed. We find also another form of cornice introduced occasionally, with modillions consisting of two plain faces, instead of consoles, without any band below, either plain or denticulated. Examples of this are only to be found in the frontispiece of Nero, at Rome, and the Poicile, or Portico, at Athens. In some instances, an uncut dentil band is substituted in place of dentils, and in the temple of Antoninus and Faustina, both dentils and modillions are omitted.

The above disposition inverts the order of the original hut, as well as the description given by Vitruvius. The only example where dentils are placed above modillions, is in the second cornice of the Tower of the Winds, at Athens; although Vitruvius seems to assert that the contrary practice of placing the modillions uppermost, was never resorted to by the Greeks. It is certain that the Romans employed modillions in the latter position, as is evidenced in the temples of Jupiter Tonans and Jupiter Stator, as also in the Forum of Nerva.

If the entablature be enriched, the shaft should be fluted, unless it be composed of variegated marble; for a diversity of colours confuses even a smooth surface; and if decorated, the ornament increases the confusion in a much greater degree.

When the columns are within reach, the lower part of the flutes, to about one-third of their height, is sometimes filled with cables, as in the case of the interior order of the Pantheon, with a view to strengthen the edges. In rich work of some modern buildings, the cables are composed of reeds, husks, spirally-twisted ribbands, flowers, and various other ornaments: but these trifles, which are of French origin, would be much better withheld, as their cost would be employed to greater advantage in giving majesty or grandeur to the other parts of the fabric.

As the cornice, which has obtained the name of Corinthian, consists of so many members, it will be necessary to increase the whole height of the entableture more than two diameters, so as to make the members distinct, and, at the same time, to preserve a just proportion between the cornice, frieze, and architrave, making the height of the entablature two-ninths of that of the column: but where the Ionic cornice, which is very appropriate, is to be employed, or the dentils and their cymatium omitted, two diameters, or a fifth of the height of the column, will be sufficient.

It is by some considered ridiculous to give so many members to the cornice, since, say they, it is evident that these slight columns are incapable of bearing an entablature of the same part of their height, as columns of fewer diameters are. Notwithstanding this, however, we cannot but think that the richer and deeper cornice is more in keeping with the character of the order, on account of the increased height and enrichment of the capital. The apparent weight does not depend so much upon the real bulk, as upon the arrangement and proportions of the different dimensions, for were this the case, we might successfully employ the argument produced by those who object to the loftier entablature, to disparage the beauty of the entire order. We might reason thus:—the Corinthian shaft is of the same proportions as the Ionic, and therefore equally light in appearance, how contrary to sound taste, is it, therefore, to load it with a capital of so much greater bulk, how much heavier the column will appear! Our objectors will readily see that this reasoning is false, because it is evident to the senses, that the Corinthian column, although surmounted by a capital of much greater bulk than the Ionic, has a much lighter and more elegant appearance; and what is the cause of this? It is simply that the proportions are regulated in a different manner; in the Ionic the breadth is in excess, in the Corinthian the height. But there is another reason for the comparative lightness of the Corinthian capital; it is much more highly enriched than the Ionic, and this enrichment tends to make it a vast deal lighter in appearance; the difference between the unshapen block of stone and the finished capital, will be evident to any one who will picture the two in his mind's eye. Now, all these arguments apply with equal truth in the comparison of the two entablatures; for our own parts, we think the larger the more elegant and the more imposing, and certainly its cornice gives the more complete finish to the whole order.

"The symmetry of the capital," says Vitruvius, "is as follows:—the height of the capital, including the abacus, is equal to the thickness of the column at its lower end. The breadth of the abacus is so regulated, that its diagonal, from angle to angle, may be twice as great as the height of the capital; for this gives a proper dimension to each face; the fronts of the capital are bowed, or curved inwardly, from the extreme angles, a ninth part of its breadth. The bottom of the capital is as thick as the top of the column, without the apothesis and astragal. The thickness of the abacus is the seventh part of the height of the capital. The remainder, when the thickness of the abacus is deducted, is divided into three equal portions, of which one is given to the lower leaves; the second is for the height of the middle leaves; and to the caulicoles, or stalks, from which the leaves project to support the abacus, the same height is given. The flowers on the four sides are in size equal to the thickness of the abacus." From a comparison of ancient examples, the height of the capital varies in height from 60 minutes, or 1 diameter, the measurement of those belonging to the temple of Tivoli, to 87 minutes, the height of the Lysicrates example; the capital in the temple of Jupiter Stator measures 66 minutes. In the first case, the diagonal of the abacus is 81 minutes, in the last 97, and in the monument of Lysicrates, 94 minutes.

Thus much for proportions; how greatly they vary in different examples, will be readily seen in the subjoined table taken from Knight's Cyclopædia:—

	Height of Column.		Diameter of Base.		Upper Diameter of Shaft.		Height of Entablature.	
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
Incantada, at Salonica	23	8.6	2	5.9			5	7.75
Temple of the Winds (without base)	13	6.85	1	7.4				
Monument of Lysicrates, at Athens	11	7.67	1	2	0	11.65	2	8.218
Stoa, or Portico, at Athens	28	0.534	2	11.3				
Arch of Trajan, Ancona	23	2.7	2	4.25	2	0.25	5	6.3
Arch of Constantine	27	4.1	2	11.2	2	9	7	1.2
Portico of Pantheon, at Rome	46	5.2	4	10.4	4	3.5	10	11.6
Interior of Pantheon, at Rome	34	10.4	3	8.2	3	2.3	8	2.9
Temple of Antoninus and Faustina	46	7.7	4	10.3	4	2.8	10	9.1
Temple of Vesta, at Tivoli	23	6	2	5	2	1.8	4	3
							Architrave.	
Temple of Jupiter Tonans	46	6.2	4	8.3	3	11.4	10	0
Temple of Jupiter Stator	48	4.9	4	10.2	4	2.5	12	10.3
Temple of Vesta, at Rome	34	7.2	3	2.5	2	8.1		
Temple at Jackly, near Mylasa, in Asia Minor, the supposed site of Labranda	27	2.8	2	10.35	2	3.6	5	6.6
Temple of Mars Ultor, at Rome	57	11	nearly 6 ft.		5	1.6	3	10.5

The proportions of this order vary to a very great extent; the following may be taken as an average:—shaft, 16 modules 20 minutes, base 30 minutes, capital 70 minutes, which gives 10 diameters for the whole column; the diminution of the shaft, from the base to the neck, is 7 minutes. The entablature is about a fifth part, or a quarter the height of the column; if the latter, it would consist, in this case, of 5 modules, or 2½ diameters, of which the architrave would occupy 45 minutes, the frieze 45 minutes, and the cornice 60 minutes, having altogether a projection of 58 minutes.

Although the Romans in all probability borrowed the idea of this order from the Greeks, and cannot therefore rightfully lay claim to its invention, they are fully entitled to the praise due to its perfection; the order, as far as we know it, is rather Roman than Greek. We cannot be said to know of more than three examples in Greece, and these are the Tower of the Winds, the Monument of Lysicrates, and the Temple of Jupiter at Olympia; there are others, it is true, as the temple of Jupiter Olympus, at Athens, but this was erected long after the order had been practised by the Romans. The principal Italian specimens are the temple of Jupiter Stator, three columns of which remain in the Campo, Rome, and have been imitated at the office of the Board of Trade, London; the Pantheon, copied in the portico of S. Martin's Church; the temple of Vesta, or the Sibyl, at Tivoli, copied at the Bank; the temples of Mars Ultor, Jupiter, Capitolinus, Vesta, at Rome, Antoninus and Faustina, and of Jupiter Tonans. Copies of the columns of Choragic monument are to be seen at S. Philip's Chapel, S. James's and at the entrance to Exeter Hall; original fragments may be seen in the Elgin collection at the British Museum, where there are also casts from the Pantheon, and the temples of Jupiter Stator and Mars Ultor. Amongst all the specimens which have come to our knowledge, there are not two alike, they all vary in detail, and some very much so; some fragments bear evidence of the introduction of figures of animals, &c.

The Corinthian order is appropriate for all buildings in which magnificence, elegance, and gaiety are requisite. Its splendour also recommends it in the decorations of palaces, galleries, theatres, banqueting-rooms, and other places consecrated to festive mirth, or convivial recreation.

The Romans, in borrowing their architecture from the Greeks, appear to have indiscriminately employed the Corinthian order, which they found possessed of an ornamental character, adapted to the splendour and magnificence of their taste, in the same manner that the early Greeks used the Doric, and the Ionians the order which bear their name. Thus the Romans erected temples to Jupiter, Neptune, and Mars; and the Greeks to the same deities, of the Doric order. Thus the temples of Minerva, at Athens and at Sunium, are Doric, and the temple of Minerva, at Priene, is Ionic. The temple of Jupiter Olympus, at Elis, was Doric; but that erected to the same idol, by Adrian, at Athens, is Corinthian.

The orders of architecture appear to be altogether national; thus the numerous temples of Greece, and its Sicilian colonies, are Doric, and bear one general character: the Ionian cities present the best, the most elegant, and chaste examples of the Ionic order: while Italy, Balbec, and Palmyra exhibit the Corinthian order, almost to the exclusion of any other.

Plate I. *Figure* 1.—Nos. 1 and 2 show the method of projecting the plan and elevation of the capital: thus, beginning with the plan, divide the semi-circumference of the top of the shaft into four equal parts, commencing and terminating with half a part, which will give the stems of the lower range of leaves, then complete the contour of the leaves, both in the elevation and plan, as shown under the article PROJECTION; divide each of the parts into halves on the said semi-circumference, and the points of bisection will mark the stems of the second or superior range of leaves. But if the true forms, as ascertained by the principles of projection, be impressed on the mind of the delineator, and if great nicety be not requisite, after dividing as above, and completing the outlines of the leaves on the plan by his eye, he may then draw lines from the bottom of each stem, and from the tips of each on the plan, to their respective places on the elevation, and there complete the two ranges of leaves entirely by the eye; here the jutting points, stems, and breadths of the leaves, are the only guides in the formation of the outline. This process being only a preliminary, though necessary step to the raffling of the leaves, the general contours, thus found, must be rubbed out, after inking the subdivisions, in order to make the foliage appear.

Figure 2, is the profile of the modillions; No. 1, being the plan, showing soffit inverted; and No. 2, the elevation of the same.

Figure 3, is a leaf completely raffled to a large scale; No. 1, is the front view; No. 2, the profile or side view.

Figure 4, shows the finished flower of the capital on a large scale.

Plate II. Some few of the more noted examples of Greece and Rome.

Plate III. A finished elevation of the Corinthian base, capital, and entablature. The example here chosen, is from the three famed columns in the Campo Vaccino, at Rome, supposed to be the remains of the temple of Jupiter Stator, and certainly one of the most perfect and elegant remains of this order, that antiquity can produce.

Plate IV. A general outline of the same, with the proportions of the members figured in minutes.

CORINTHIAN ŒCUS, an œcus decorated with the Corinthian order. *See* ŒCUS.

CORNICE (from the Latin, *corona*, a crowning) any moulded projection which crowns or finishes the part to which it is affixed; thus we have the cornice of an order, of a pedestal, of a house, of a pier, of a door, of a window, &c.

CORNICE OF AN ORDER, a secondary member of the order itself, or a primary member of the entablature. The entablature is divided into three principal parts, the upper one being the cornice. The forms of the particular cornices belonging to the orders, will be found under the heads DORIC, IONIC, CORINTHIAN, TUSCAN, and ROMAN.

According to Vitruvius, the application of cornices to stone buildings originated in the juttings of the eaves of the first wooden structures, the cornice representing the uppermost beams of the roof, which are described by this author as assers, templates, and canthers, of which the last is supposed to apply to the common rafters, the first to the timbers immediately beneath the tiles, and the templates to the cross pieces between the two. The mutules represent the ends of rafters, and dentils the ends of laths for supporting the tiles, or covering; but as the lath is more lofty in situation than the rafters, so ought the dentils to be more lofty than the mutules: this, however, is not the case in the joint application of these members in modern cornices.

Our present practice of architecture was borrowed from the Romans, who, in all their works, inverted the natural disposition of these members. Vitruvius remarks, "as the mutules represent the projectures of the canthers (rafters), the dentils of the Ionic order are in imitation of the projecture of the assers (laths). For this reason, in Grecian buildings, dentils are never placed under the mutules; for assers cannot be under canthers. As, therefore, they should be above the canthers and templates, if they are represented below them, the work is on false principles. The ancients, likewise, did not approve of placing mutules or dentils in the fastigium, but in the corona only; because neither canthers nor assers are laid towards the front of the fastigium, nor can they there project, for they are laid inclining towards the eaves. As, therefore, it could not be done in reality, they judged it not proper to be done in representation, for the propriety of all things, which they introduced in works of perfection, they derived from truth and nature, and approved only those which could bear the test of rational argument."

We have no example, in the remains of well-authenticated Grecian antiquity, of cornices, where both modillions and dentils are employed, except in the inner cornice of the Tower of the Winds, at Athens: in this instance, the assertion of Vitruvius is completely verified; for there the dentils are placed above the mutules: but in every Roman example, where both are employed in the same cornice, the very reverse takes place; yet, with respect to pediments, we have an example in the frontispiece of the doors of the said Tower of the Winds, where dentils are employed in the inclined cornices of the pediments, contrary to the observations of Vitruvius, and to the original principles whence, according to his theory, these members derived their existence.

In the cornices of all Grecian edifices, particularly those of the Doric order, we always find one very bold member, with a broad vertical face, called *the corona*, which is one of the most distinguished members of the whole cornice: but in some of the Roman buildings, the corona is reduced to a mere fillet. *See* CORONA.

CORNICES are divided into several kinds:

An *architrave cornice* rests upon the architrave, and the frieze is omitted. An instance of this may be seen in the famous Caryatic portico, at Athens. Cornices of this description are adapted to situations where a regular entablature would be out of proportion to the body which it crowns.

A *mutule cornice* is appropriate to the Doric order, the mutules having inclined soffits.

A *dentil cornice* has a denticulated band, and is usually employed in the Ionic order, though very appropriate also for the Corinthian.

A *modillion cornice* is one with modillions, which are a kind of mutules carved into consoles. It has been chiefly applied to the Corinthian order.

A *block cornice* is that where plain rectangular prisms with level soffits are employed to support the corona, instead of mutules.

A *cantaliver cornice* is constructed of a horizontal row of timbers, projecting at right angles from the naked part of a wall, for sustaining the superior parts of the cornice. Sometimes the cantalivers are placed on the soffits and vertical sides, and sometimes they are cased with joinery.

A *coved cornice* is one with a large cove, and generally lathed and plastered upon brackets. Cornices of this kind are hardly used at this time, but are frequently found upon old houses.

A *mutilated cornice* has some, or the whole of its members interrupted by another object, as the projection of a tablet, &c.

CORNUCOPIA, or CORNUCOPIÆ, the horn of plenty. Ovid tells us in his "Fasti," that one of the goats of Amalthea, who nursed the infant Jupiter in Crete, broke off its horn against a tree, when the nymph having wreathed it with flowers, and filled it with fruit, presented it to the god. When Jupiter came into power, he called Amalthea to the skies, and made the horn the emblem of fertility. In the "Metamorphoses," the poet derives the origin of the Cornucopia from a different fable. He speaks of it as the horn of the river-god Achelous, broken off by Hercules, and consecrated by the Naiads. The real meaning of the fable is this, that in Libya there is a little territory, shaped something like a bullock's horn, exceedingly fertile, given by king Ammon to his daughter Amalthea, whom the poets feign to have been Jupiter's nurse.

In architecture and sculpture, the cornucopia, or horn of plenty, is represented under the figure of a large horn, out of which issue fruits, flowers, &c. On medals, F. Joubert observes, the cornucopia is given to all deities, genii, and heroes.

CORONA (from the Latin) a member of the cornice, with a broad vertical face, and a bold projection. The solid, out of which it is formed, is generally recessed upwards from its soffit; hence the Italians call it *dgocciolatios* and *lagrimatios*, the French, *larmier*, and the English workmen, *drip*, from the circumstance of its discharging the rain-water in drops from its edge, and by this means sheltering the subordinate parts below.

The corona is one of the principal members of the cornice and that which marks its distinctive character, by the massive shadow which it produces on the plain surface of the frieze. This member, from being the principal feature of the cornice, ought never to be omitted.

Grecian antiquity affords no instances of an order without a corona; nor, indeed, are there many examples among the Romans.

There is nothing in architecture better supported by reason, and by the general example of antiquity, than the necessary use of the corona. It is, however, omitted in the temple of Peace at Rome, the third order of the Coliseum, and the arch of Lyons, at Verona. It is singular, that in the arch of Constantine, the cornice finishes with the corona, surmounted with a fillet only; and in several other examples the corona has almost dwindled into a mere fillet. The frontispiece of Nero presents one of the boldest coronas of all the Roman works, being very nearly 16 minutes in height; the three columns in the Campo Vaccino is another example of an elegant and bold corona. In the temples of Minerva and Theseus, at Athens, it is divided into two faces. The term *corona* is sometimes applied by Vitruvius to the whole cornice, the word originally signifying a *crown*.

CORONA LUCIS, a kind of chandelier anciently employed in churches, of beautiful and appropriate design, and admitting of delicate elaboration.

COROSTROTA, according to Pliny, a kind of inlaid work.

CORPS, (from the French) any part that projects or advances beyond the naked of the wall, to be used as a ground for some decoration.

CORPSE-GATE, the same as LICH-GATE, which see.

CORRIDOR, (from the French) a long gallery or passage around a building, leading to the several apartments; sometimes open one side, and sometimes enclosed on both sides.

CORSA, the same as PLATBAND, which see.

CORTILE, a small enclosed court.

COSSUTIUS, a Roman citizen, who was architect to the temple of Jupiter Olympus, at Athens.

COST, in building, the expense of any design, a knowledge of which is to be obtained by analyzing the whole, and making separate calculations of the quantity and expense of each part. In buildings of a similar description, the expense of the whole can be roughly ascertained, by taking the number of cubic feet at an average rate; but when the price of materials or labour, or of both, is subject to variation, this method will be liable to mislead.

COTTAGE, a name mostly applied to a small house, erected for the use and accommodation either of the farm labourer, or those engaged in some other occupation, but more generally of those employed in agriculture.

The word cottage is also used in modern parlance to designate a small elegant residence, more properly a villa, or, as sometimes called, a cottage ornè. Houses of this description, however, do not belong to our present subject, which must be understood as treating of the cottage in the acceptation of the term explained in the preceding paragraph.

Cottages were formerly constructed of rude and perishable materials; as, earthy substances mixed with straw; and cottages of this consistence were denominated *mud cottages* in some districts, and *cab and dab* in others; but these have now given way to a more durable kind, which, though perhaps as expensive in the erection, are much more comfortable, and cheaper in the end, as they require little or no repairs for many years.

In the construction of cottages, economy, convenience, cleanliness, comfort, and decency, must be the chief points in view, and these ought to be united with as much picturesque beauty as circumstances will admit.

"The accommodation required," observes Mr. Dean, in his very interesting work, "Essays on Agricultural Buildings," "is not such as would be looked for by persons moving in a higher sphere of life, and who are accustomed, comparatively, to luxuries; the labourer belongs to a totally distinct class of society. Let the dwellings of the poor be scientifically constructed, and much illness and misery will be prevented. In effecting this, the whole community is interested, as parochial expenses are increased or diminished according to the healthy state of the labouring population.

"Cottages should be warm and substantial; judgment will also be displayed when the architectural character of the building is in harmony with its use. Their exteriors may be made exceedingly ornate by the application of a correct taste, which does not necessarily create much expense; and although ornament is not a necessary appendage to stability or comfort, it frequently happens that ornamental buildings are preferred, and when judiciously disposed, will materially assist in heightening the landscape. It then becomes a question with the owner of an estate, whether he will, in the erection of cottages, incur a small additional outlay for this purpose.

"England has justly been designated a cultivated garden, and perhaps in no particular possesses a greater pre-eminence of appearance over other countries, than in the beauty of her rural scenery; which, it is submitted, may be greatly enhanced by the substitution of cottages erected in accordance with architectural principles, in lieu of the clumsy-looking and comfortless buildings existing in many districts."

We fully agree with Mr. Dean in these observations, and we trust that noblemen and gentlemen in the management of their estates, will not only provide for the comfort of the poor in the erection of warm, well-constructed cottages, but that they will add some little in the way of ornament also. How much may the picturesque appearance of the cottage be increased by entrance-porches, overhanging roofs, and stacks of chimney-shafts, having ornamental summits. The porch, independent of its architectural effect, affords both warmth and shelter, as does also the overhanging roof. The lofty chimney clustered shafts, besides assisting to prevent a smoky room, have a very pleasing appearance.

In the erection of cottages, it is preferable to build them in pairs if possible, as the cost is considerably less than when singly placed, and they are much warmer. The *site* also is a most important consideration, as houses placed on low marshy soils, are liable to be damp. Independently of the miasma arising from the surface of the ground in such situations, there is a continual humidity in the atmosphere, which communicates itself to all objects surrounded by it. This vapour is a deadly poison, acting on the human system through the medium of the lungs, and producing fevers and other epidemics.

Good drainage is the next important consideration, and this may generally be obtained at small cost. The common earthenware pipes, of an oval or egg-shaped form, about 5 inches by $2\frac{1}{2}$ inches at bottom, are sufficiently capacious to carry off the drainage from a cottage; they are not so costly as brick-drains, and are more efficient.

All drains should be trapped with a syphon trap, so as to prevent the escape of foul air, and the admission of vermin to the dwelling. The drains should communicate with a cesspool sunk in the garden, domed over with brick, having a stone man-hole or flap to eanable the cottager to repair or cleanse it; or to avail himself of its contents for manuring his garden. A drain should also lead from the sink in the scullery to the cesspool (trapped as before described), and this should be so arranged as to carry off the water used for washing the floors, when they are of stone, brick, or composition. The cheapest and best form for the cesspool is that of a parallelogram about 5 feet long, 2 feet 6 inches wide, and 3 feet 6 inches deep.

Cottages may be divided into several classes, or sizes: one of the smallest size for the common labourer; the second size for the labourer, who, by his frugality and industry, in earning more than ordinary wages, deserves a more comfortable dwelling than that of the most common labourer; the third size, for the village shopkeeper, shoemaker, tailor, butcher, baker, &c.; the fourth size, for the small farmer, maltster, alehouse, or other trades, requiring room; the fifth size, for the large opulent farmer. Every cottage should have at least two apartments, and in many cases three, or even four. If the apartments be two in number, and in two floors, one roof will cover both; but then there must be the expense of an additional floor, and a stair to get up to it, besides a loss of room in both floors, for the space occupied by the stairs; however, with respect to a sleeping apartment, a room in an upper story is more healthy than in a lower. In cottages which are built singly, the families are less liable to contention than in those which are joined: but in those which are built together, a considerable expense of walling will be saved, as the flues may be carried up in one common stalk, and in case of sudden trouble, one family may assist another.

Where a cottage consists of two stories, with a sleeping-room in the upper one, it would tend much to the comfort of the cottager, if the upper story were warmed by means of a flue from the fire below; for this purpose, the vent ought to be carried up the middle, with its sides as thin as possible. Another mode, suggested by Mr. Beatson, is to permit the heated air, which always ascends from the ceiling of the lower story, to ascend through an aperture in the floor of the upper story; this may be done by means of gratings, or turning-plates, in the least frequented part of the floor.

With respect to economy, Mr. Loudon, in his treatises on country-residences, has suggested a plan, by which he thinks much more heat may be thrown out from a given quantity of fuel, than by any other method yet proposed, and even by more simple means. The grate which contains the fuel being placed on a level with the surface of the floor, makes the smoke ascend slowly, and thus in its passage allows it time to give out its heat. In small cottages, the staircase ought to be so constructed, as to take up as little room as possible.

The chief conveniences of a single square cottage, are an eating-room of about 12 feet square; over this a sleeping-apartment, which may be partitioned in such a way, as will best accommodate the decency to be preserved in the family; an idea of this construction may easily be formed without a plan. If the dimensions of the buildings be two or even three feet more, it will give much more advantage in point of convenience. For cottages built in rows, the accommodations may be as follow: a room below, of 16 feet square, with the entrance-door and one window in front; the fire-place with an oven opening into it by means of a flue; a door opening

into a lean-to, at the back, for covering fuel, the tools of the labourer, and sheltering for a pig, &c.; a pantry, fitted up with shelves, may be made under the stairs, in the lower room.

To accommodate a large family, with children of different sexes, the necessary separation may be effected, by placing one bed over the other, and the entrance to each of the beds on alternate or different sides.

There are two kinds of cottages, English and Scottish, used in Great Britain, of very distinct characters.

The old English cottages were constructed of clay, turf, and other similar materials, supported and strengthened by posts and wooden braces, with a roof of very steep pitch, in order to lessen its pressure upon the walls, and to discharge the rain. The eaves of the roof were continued downwards, so that the projection might throw the water from the surface of the walls, and by this means prevent not only the waste of materials, but the dampness which the interior would otherwise be liable to; the rain-water also thus kept from the windows and door. The chimneys were generally carried up singly, in one or both ends of the building, most commonly on the outside of the wall. The covering of the roof consisted principally of straw, reeds, or slate-stone. Garrets were sometimes formed in the roof, with a window, either in the sloping sides, or in one of the gables. In consequence of the lowness of the side-wall, and to give sufficient light, the horizontal dimension of the window was much greater than the height. The long bearing of the lintel, or head of the window, was supported in the middle by an upright piece of timber, called a *munnion.* The glass-frames were made to revolve upon hinges with a vertical axis, glazed with small squares of glass, inserted in lead, and stiffened by cross pieces of wood, or frequently iron, called *saddle-bars;* the form of the squares sometimes rectangular, but frequently rhomboidal, and the lead into which they were inserted fixed to an iron frame. To this construction the cottager frequently added a small shed, for keeping a cow, and sometimes one or more hovels to the end of the side, which might be used as a pantry, or as a place wherein to deposit his tools, or other articles of convenience. It is probable that cottages were at first built of a single story only; but, in course of time, they were constructed two stories in height, and as the lower story could not then be protected by the roof, a projection of wood or slate-stone was introduced over the lower apertures, to prevent the rain-water from falling upon the wall. To make these projections ornamental, they were formed into labels of hewn-stone, after the manner of those in Gothic edifices.

The width of the English cottage does not admit of more than one room: the chimneys are variously ornamented, sometimes several flues are united in one shaft, which is built in a variety of fanciful forms, and sometimes several shafts are carried up separately, and united under one cope.

The best English cottages, of late, have been generally constructed of brick, and covered with slate: and the use of these materials has changed the external features very considerably, though the general disposition of the parts remains much the same.

The roofs of many English cottages are partly gabled and partly hipped; and in general the roof is extended at both ends, so as to oversail the gables: the projection thus affording protection to the walls in the same manner as the eaves over the front and rear walls; by this means the gable-tops, being under cover, are less liable to want repair. The walls of English cottages are generally adorned, either by whitewashing or colouring the walls; or with creepers of various kinds.

The Scottish cottages differ considerably in form and features from the English, not only in being generally constructed of stone, which is the material most easily procured in the country, but from their being so wide as to admit of two apartments; and being commonly one story only in height. One of these circumstances is sufficient to occasion a great dissimilarity when compared with the proportion of the English cottage, in making the roof top-heavy, and the general appearance of the building squat; and when both are united, this effect will be still more apparent.

In the Scottish cottage, the roof has only a very small projection over the walls; the windows and doors are generally plain; the gables most frequently surmount the roof; the apertures of doors and windows are therefore not so well protected from rain as in the English cottage; but this want of projection is counterbalanced by the great thickness of the walls, and by the narrowness of the windows, which are made to slide in a vertical position, in grooves on the sides of a surrounding frame.

An inducement to make the windows narrow, was the length of the stones, which would not have been easily obtained otherwise. In order to procure the greatest quantity of light, the sashes were glazed with planes of glass comparatively much larger than those used in English cottages, and the sides of the windows were splayed from the glass-frame, so as to form very obtuse angles with the interior surface of the wall. The windows of the Scottish cottage are thus not only very different from those of the English, in being without dressings, and of a different proportion, but also in their manner of glazing and shutting them. The chimneys are either carried up in one or both gables, or in a partition-wall, which separates the two apartments in the length: when carried up in the ends, as the walls are always made sufficiently thick to receive the flues, the walls are not recessed upon the flanks of the stalk of chimneys, in order to save materials. These, consisting of crude stone cemented with mortar, being of little value. The chimney shafts, or the turrets surmounting the roof, are generally plain, finished on the top with a coping of hewn-stone.

In many old constructions of Scottish cottages, the chimney is placed in the front-wall, with a large recess all round the fire, which gave great advantage, in admitting more than double the number which the modern construction admits of, and was therefore useful in times when the master and his servants sat in common with each other. In the old constructions, the roof was covered with thatch, turf, or heath, as being the most ready materials; but these, as in England, have generally given place to the more durable coverings of slate and tile, for similar reasons.

Few appendages are used in Scottish cottages; and in days of old, so little attention was paid to cleanliness, that the cottager who was blessed with a cow, admitted the beast to lodge at night in the same house with himself, without any other partition than the back of a bed or press, to separate his apartment from that of the animal. We are, however, happy to find, that among many other improvements in the north, comfort and cleanliness are now as much objects of the wishes of the inhabitants, as in other parts of the United Kingdom; but even in the present time, from the impression of ancient forms, though the cow-house be separated from the cottage, they are still in one continued formal line, and want that picturesque beauty which an appendage would give, as in the English cottage.

The common kind of the present cottages in the north, are made very wide, either to receive a framed bedstead and press, or to form recesses, by means of a partition, for the reception of the bed and cupboard, on the side of the apartment opposed to the window.

The gables on some old cottages in North Britain, are surmounted with steps, following the sides of the roof, instead of the plain coping, which formed the thatch-way.

Scottish cottages are frequently decorated by training honeysuckles or ivy upon the walls, and a row of house-leek is disposed along the ridge, and not unfrequently upon the sloping sides, in case of a thatched roof.

The materials to be used in the erection of cottages will necessarily depend in a great measure on the locality in which they are to be built. Cottages are built of clay, or turf, bricks with wood, crude stone, flint, large pebbles, *cab*, &c.; those used for the covering are turf, straw, tiles, slate, tarred paper, tessera, &c. When fir abounds, as in the north of Scotland, this timber may be used both for boarding and scantling; in places yielding stone—that material with flag-stones—for roofing.

In some parts of Lancashire, houses are built with a framework of wood, filled up with wattled shed-work, and afterwards covered with a composition of clay and wet straw, locally termed "clot and clay;" this, when plastered and limewhited, has a neat appearance. In Devonshire, walls of a similar character are called "cob-walls;" in France, *pisé*. Houses in the departement of the Isère, Rhone, and Din, the walls of which are formed with this material, have existed for upwards of a century, and effectually resist the inclemency of the weather.

Clay may be used with advantage in a similar manner in this country if properly prepared, and applied with judgment. It should by well tempered, and mixed with a portion of fine gravel, or sand; this facilitates the drying, and prevents the composition from cracking. In forming the walls, fix temporarily in the ground two parallel rows of poles, planked on the inner sides—a space of 20 inches between being left for the thickness of the wall: ram the prepared clay well into this space, raising the planks as the work proceeds, care being taken that the walls are carried up perpendicular. Ironhooping should be laid diagonally in the substance of the wall, as bond. Over all the openings, stout lintel should be laid; and the door and window-frames fixed as the work progresses. When the walls have *set*, remove the planks and poles, which may serve as timber for joists and rafters. After the walls are completed and thoroughly dry, the exterior may be rough-cast, and a coating of plaster laid on the interior.

A good method of keeping such walls dry, is to build in, at intervals, small perforated drain-pipes. These should be laid in the substance of the walls, the bottom resting upon a framed opening defended by a cast-iron air-brick; the top having a small orifice under the eaves leading outward. The current of air passing through these pipes will carry off all moisture exuding from the walls. The improvement of the dwellings of the industrial classes is now occupying, in a considerable degree, the attention of philanthropists. Several societies have been formed expressly to carry out so benevolent an object, and their attention has been especially directed to the erection of a better description of cottage for the agricultural labourer. The young architect, in the outset of his professional career, may possibly be called upon to furnish designs for such buildings, and with a view to assist him, we have subjoined the following specification principally taken from a work we have before quoted, Mr. Dean's "Essay on Farm Buildings." Mr. Dean is a practical architect, and is thoroughly master of the subject on which he has written; and his "Essays" may be consulted with advantage by those who are about to erect agricultural buildings.

The specification is for a pair of labourer's cottages, semi-detached, but may be altered as to materials, &c., according to locality and circumstances.

The general conditions are as usual, and it is unnecessary to occupy space by transcribing them.

"Specification.

"*Excavator*. Dig out the earth for the foundations to the several walls, drains, and cesspools, as shown in the drawings, or herein described. The cesspools to privies to be sunk outside the building. Fill up the trenches to the depth and width shown in drawings with concrete composed of one part of ground-stone lime to six of gravel, broken stone, or clean ballast. Fill in and well ram the ground-work to the trenches and walls, so as to prevent the rain soaking down to, or standing against, the walls and foundations."

"*Bricklayer*. The footings to the walls to be formed with sound, hard, well-burnt stock-bricks or burs from the brick-field, filled in solid, and well flushed with mortar. On the footings spread a layer of gas-tar and sand, and over this a course of slate is to be laid, should there be the slightest chance of dampness arising from the foundation. The cesspools to be built in $4\frac{1}{2}$ inch brickwork, steened and domed over, having stone man-holes let in. The drains from the sinks to be 3 inches diameter, of glazed earthenware, with syphon traps. The cesspools and drains to be completed previous to the walls being erected. Carry up the walls and chimneys in old English bond, leaving a space of about 2 inches in the centre of the thickness of the walls, and insert air-bricks where required. Carry up from the ceiling of each room, on corbel-stones, a ventilating flue 6 by 9 inches. All the flues to be well pargetted and cored out at the completion of the works. The chimney flues not to be gathered over sharply, and twisted as much as possible.

"The external walls are to be faced with best red stock-bricks, white Suffolk bricks being used for plinths, quoins, and dressings to windows and chimney-shafts; all of which are to be carried up in the manner shown in drawings. No wall to be, at any time during the progress of the works, more than 4 feet higher than any other wall. No indents or toothings will be allowed, and no four course of bricks to exceed $11\frac{1}{2}$ inches in height.

"All the brickwork must be worked in sound regular bond, with a close joint neatly struck; every course well flushed in with mortar, and the whole made perfectly level, straight, and perpendicular. The chimney openings to have chimney bars to turn up at each end. The quarter partitions to be brick-nogged with bricks, laid flat, and well bonded.

"All openings to have arches turned over them, with proper skew backs, and left neatly pointed. The chimney and jambs are to be chamfered, to have plinths, and two projecting bricks, cut, as shown in drawing, to support mantel shelf. The fire-places are to be lined with fire-bricks, and an oven built at back. The bottom, sides, and top of oven to be of fire tiles, with flues for carrying the fire under and up the sides of the oven. The smoke-flue to be provided with dampers, and a door provided with damper leading to the oven, which is to be fixed in chimney jamb. Fire-grates are to be formed by letting round iron bars into the brickwork of fire-places.

"The privies to be provided with Boulton and Watt's closet-pans, and glazed earthenware pipes leading to cesspools. The boilers to be set with rounded bricks, and the inside work, where exposed to the fire, lined with fire-brick. The mortar to be composed of one part of good lime to three of sharp sand, or fine-sifted gravel; the whole to be well tempered. Properly bed all lintels, plates, frames, and sills; point round all frames and sills; stop all putlock holes, and leave the works in a complete state.

"*Mason and Paviour*. Provide and fix 4 inch tooled York stone steps to porches and entrance-doors. Provide and fix 3 inch York stones over cesspools; 4 inch stones for corbels, to carry brickwork to air-flues; a circular space about 4 inches diameter, to be cut in these stones, and a ventilating valve inserted in each. Inch hare-hill hearths, and back-hearths to all chimney openings, with stone-kirbs round to act as fenders. The kitchens to have ash-pits with iron movable gratings over. Sink-stones to wash-houses 2 feet 6 inches by 1 foot 9 inches, out of 7 inch stone, properly dished (or wood lined with zinc may be used), each sink to be provided with a bell-trap. Pave the porches and pantries with 10 inch tiles, well bedded, the ground being previously well rammed. The rest of the ground-floors to be made with concrete. Two-inch York stone treads, and risers to stairs, properly cramped, and supported by dwarf brick walls. The floors of privies to be paved with $1\frac{1}{2}$ inch York stone."

"*Carpenter*. The fir timber to be free from sap, large knots, and shakes. The oak to be English, die-square. The framing to be executed in the most approved manner, and to be of the following scantlings:—Wall-plates $4\frac{1}{2}$ by $2\frac{1}{2}$; lintels over all openings, 4 by 4; chamber-joists 7 by $1\frac{1}{2}$, 12 inches apart, with bays of herring-bone struts 2 feet apart, thin iron hooping being nailed to the under side of the joists, and the space between the joists to be filled up solid with broken stone or clay and mortar. Trimming-joists 7 by 3; struts 4 by 2; partitions to have heads and sills 4 by 3; uprights and braces 4 by 2. Door-frames chamfered on the edges 4 by 3; rafters $4\frac{1}{2}$ by $2\frac{1}{2}$; purlins 4 by 3; collars to every sixth pair of rafters, 6 by 2; ridge, 7 by $1\frac{1}{2}$; $\frac{3}{4}$ yellow deal battens to carry slates. Provide and fix 2 inch cut and splayed barge-boards, with pinnacles, &c., as shown on drawings."

"*Joiner*. External doors to be square-framed and battened, hung with 4 inch butts, with 7 inch drawback locks, 6 inch round bolts, (3 to each door,) and Norfolk thumb-latches; $\frac{3}{4}$ ledged internal doors, and $\frac{3}{4}$ ledged privy, pantry, and coal-closet doors, with bolts and latches. The doors to have inch jamb-linings and stops."

"*Windows*. Solid deal frames, $4\frac{1}{2}$ by 3, with oak-sunk sills; $1\frac{1}{2}$ ovolo sashes, suspended by pivots; those in the pantries to be filled with perforated zinc."

"*Fittings*. Inch deal seats and risers to privies, on fir carriages. The seats to have flaps hung with $2\frac{1}{2}$ inch butt hinges; 1 shelf to be fixed round each cupboard closet in bed-rooms, and 3 in those in kitchens: $1\frac{1}{2}$ inch dresser-tops, and 3 shelves to pantries. Angle staves to be provided and fixed to all angles; $\frac{3}{4}$ clamped shutters to dwelling-rooms, hung as flaps, with deal framed brackets, to be turned on pivots, the flaps forming tables. Fir mantel-shelves, 6 by 2 inches, over each opening."

"*Plasterer*. The walls of the dwelling-rooms and bed-rooms to be rendered and set. The ceilings and rafters lathed with iron hooping; the space between the joists and rafters filled up solid with broken stone, or earth and lime. The ceilings to be plastered, set, and whited. The chamber floors to be laid with floor plaster, and trowelled to a smooth surface. The walls of the sculleries, pantries, coal-closets, and privies, to be twice lime-whited; cement skirting, 6 inches high, to be run round all the kitchens and bed-rooms."

"*Slater*. Cover the roofs with countess slates, laid hollow to a proper guage. The ridges to be of slate, bedded in cement."

"*Ironmonger*. Fix No. 8 $1\frac{1}{4}$ round iron bars to all the fire-places, to form stove. Fix iron pans in sculleries. Fix where directed an iron pump, with double handle; fix No. 4, stacks of 4 inch descending pipes, with cistern heads and shoes, the bottom length to be of cast iron. Provide and fix No. 12 cast iron air bricks, to be fixed where directed; fix No. 8 Arnott's valves where directed. Fix perforated zinc-plates to doors of rooms not having chimney openings in them. Provide No. 10 chimney bars, to turn up at each end."

"*Plumber*. Inch lead waste pipes from sinks to drains curved round so as to form stink-traps, and provided with bell-traps. Lead flashings to chimneys, 5 pound to the foot super. Provide and fix 15 feet of $1\frac{1}{2}$ suction-pipe from well to pump."

"*Glazier and Painter*. Glaze the several sashes with 3d Newcastle crown glass. Stain the whole of the wood-work of the exterior with a composition of gas-tar and Roman ochre, laid on when boiling hot. The interior to be stained with 'Stephen's stain,' and afterwards varnished."

The above Specification is so carefully drawn, that we have thought it expedient to extract it entire, as a useful guide to the young architect. It may, of course, be altered according to circumstances, and it may not always be desirable to incur so large an outlay. The estimate for a pair of cottages similar to those specified, would range from £200 to £300, according to the amount of ornament bestowed on them.

COUCH, in general, the lay of any mucilaginous substance on any material, as wood or plaster, in order to protect the surface of that material from the weather, and thereby render it more durable, or less vulnerable to the corroding influence of the atmosphere.

Couch, in painting, denotes a lay or impression of colour, whether in oil or water, with which the painter covers his canvass, wall, wainscot, or other material to be painted.

Paintings are first covered with a couch of varnish. A canvass, to be painted, must first have two couches of size before the colours are laid: two or three couches of whitelead are laid on wood before the couch of gold is applied.

COULISSE, French; the pieces of wood which hold the floodgates in a sluice; also any timbers having grooves in them.

COUNTER, COMPTER, (from the Latin, *computare*) the name of two prisons in London, for the use of the city, to confine debtors, breakers of the peace, &c.

Counter, a term formerly used among engineers to denote the superintendent of a canal, or other great work, under the resident-engineer. His business was to keep an account of the time of the men employed, not only in different departments of the work, but in different soils also, as a check on the charge of the men; and thereby to enable the resident-engineer, who received his accounts, to ascertain the rate of any quantity of common measure in similar operations. The counter seems to have been the same as what we now call clerk of the works.

Counter Drain, a ditch or channel parallel to a canal or embanked water-course, for collecting the soakage-water by the side of the canal or embankment, to a culvert or arched drain under the canal, by which it is conveyed away to lower ground.

Counter Drawing, the copying of a design by means of a fine linen cloth, oiled paper, &c., laid on the drawing; the strokes of the drawing appearing through the transparent cover, being traced and marked with the pencil.

Sometimes drawings are copied on glass, or with frames or nets divided into squares. The pentagraph is not only

useful in making fac-similes, but for reducing or enlarging drawings in any proportion; but of all instruments employed in copying rectilinear or regular curved-lined drawings, or mixed of the two, the proportional compass is the most accurate, the most expeditious and convenient instrument ever yet invented; and if the parts of the drawing stand at different oblique angles, a pair of triangular compasses will be necessary to assist in taking the angles. Although the pentagraph will of itself enlarge or reduce, or make equal, and find the quantity of the angle, it requires much room, and for drawing straight lines and curves, the tracer to be drawn along a straight-edge. In retrograding or retracing a line in the same path, towards the contrary extremity to which it was drawn, the representative line is liable to be doubled. The pentagraph is therefore a cumbersome and inaccurate instrument for such purposes, and should only be used in reducing for rough or sketch-maps, &c., where great accuracy may not be absolutely necessary.

Counterforts, projections of masonry or brickwork from a wall, built at regular intervals, in order to strengthen the wall, or to resist a pressure of earth behind it, the counterforts increasing the breadth of its base, and thereby aiding the resistance against the power which tends to overturn it.

Counter Guage, in carpentry, a method used to measure the joints by transferring, *e. g.* the breadth of a mortise to the place of the other timber where the tenon is to be made, in order to adapt them to each other.

Counter Lath, in tiling, a lath placed between every two guaged ones, so as to divide every interval, as near as can be judged by the eye, into two equal intervals.

Counter Light, a window opposite to anything which makes it appear to a disadvantage: a single counter light is sufficient to take away all the beauty of a fine painting.

Counter Parts, of a building, are the similar and equal parts of the design on each side of the middle of the edifice; they are absolutely necessary to the character of a Grecian or Roman edifice, but in Gothic buildings a duplicature of parts is not requisite.

COUNTRY-HOUSE, as its name implies, one erected in the country. In the erection of these, under a liberal employer, the architect has the greatest scope for his fancy, ingenuity, and skill in contrivance. He is not confined to space, as in town-houses, and therefore has it in his power to extend in any direction consistent with the nature of his design. For farther information, *see* Villa, and House.

COUPLE-CLOSE, a pair of spars of a roof.

COUPLED COLUMNS, those which are disposed in pairs, making a narrow and wide interval succeed each other alternately. Of this disposition of columns, ancient architecture affords no instance; for, although in the temple of Bacchus at Rome, the columns are coupled, or stand in pairs, still the intervals between are all equal. The only use of coupled columns is in low colonnades, or porticos of edifices which have large piers, where the employment of single columns would have a meagre appearance. The ancient disposition of columns in the same range was always beautiful, on account of the proportion of the intercolumn being always narrow. In the application of columns to modern architecture, the intercolumniations must be regulated by the apertures of our domestic edifices, but the ancients were under no such restrictions. The perspective succession or gradation of coupled columns, is not so harmonious as when columns stand single. If a design be well suggested, there will be little occasion for their employment. *See* Column, Colonnade.

COUPLES, rafters framed together in pairs, with a tie, which is generally fixed above the feet of the rafters. This mode of framing is used in the ordinary houses of Scotland, without either principals or purlins. The rafters called *spars*, are most commonly notched, and the tie which couples them is also notceed with a dovetail. In a building about 25 feet wide, the spars may be 7 inches at bottom, 6 inches at top, $2\frac{1}{2}$ inches thick, and about 2 feet 2 inches apart, for boarding covered with slate.

Couples, *Main*, or Main Couples, the same as trusses for roofs, which support the roof in different bays: this term is also used in the north.

COURSE, a continued level range of stones or bricks in a wall, as far as the solid part runs. It sometimes happens, that a course of masonry is only laid to a certain length, and the other part or complement divided into two courses, in the same height as the single course; but this ought not to be admissible, and should be specified against, in countries where the contractors are ready to take every advantage in order to save the expense of larger stones, or to accommodate themselves with those already at hand.

Course of the Face of an Arch, the arch-stones, whose joints radiate to the centre. In stone work, the arch-stones are called *voussoirs* or *ring-stones*, in the face of the arch, and each radiating part consists of one stone only. In brickwork, each part, of one thickness of brick, sometimes consists of several bricks in length: but whether one or several bricks be contained between two adjacent radiating joints, the quantity thus disposed is called *a course*.

Course, in slating and tiling, a row of slates or tiles, disposed with their lower ends in the same level, which line may either be a straight line or a circle.

Course of Plinths, the continuity of a plinth in the face of a wall, to mark the separation of the stones. The course of plinths is otherwise called *string course*, which is most frequently executed with stone, but sometimes also with plaster, to save expense.

Course, *Barge*. *See* Barge-Course.

Course, *Blocking*. *See* Blocking-Course.

Course, *Bonding*, that which is farther inserted into the wall than either of the adjacent courses, for the purpose of binding the wall together. Two bonding-courses lapping upon each other, one from the face, and the other from the back, make excellent work: these courses should be placed so as to leave regular intervals for stretching courses between them, on each side of the wall.

Course, *Heading*, the same as Bonding-Course. *See* the last article.

Course, *Springing*. *See* Springing-Course.

Course, *Stretching*. *See* Stretching-Course.

Coursed Masonry, that in which the stones run in courses.

Coursing Joint, the joint between two courses.

COURT, an hypæthral, or uncovered area, either in front of a house, or surrounded entirely by the walls. As it is impossible on the same floor to light apartments surrounded with other apartments on all sides, and these again completely covered with other apartments, it will be impossible to execute an extensive building, which may have more than three rooms in length and breadth, and more than one story in height, without the intermediate rooms being entirely dark, or receiving their light by secondary windows from the exterior rooms; hence the necessity of introducing as many intermediate courts as the extension of the building, with regard to the number of rooms, both in length and breadth, may require, will be obvious. Mr. Barry has made advantageous use of a court of this description in the Travellers' Club-house. *See* Club-House. It is true, that a building can be executed without courts, and that it may contain any number of rooms; but it must have only two rooms in

breadth, or otherwise the plan cannot be a simple rectangular figure. Courts may be ornamented in the most elegant manner, and being more confined than the external parts of the edifice, the ornaments may be of a more delicate nature; and if any parts of the building can admit of arcades, or of two or more orders, one above the other, a court is certainly the most susceptible of such decoration. We are informed by Vitruvius (book vi. chap. iii.) that the ancients had five kinds of courts, called *cavædii*, distinguished by the denominations of *Tuscan*, *Corinthian*, *tetrastyle*, *displuvinated*, and *testudinated*. For the description of each, see Cavædium.

COUSINET, Coussinet, a Cushion, a stone placed upon the impost of a pier or pedroit, for receiving the first stone of an arch. If the arch be the segment of a circle, the cousinet may be an isosceles triangle, with the base upon the impost, and the two sloping sides radiating to the centre; or if the arch be a semicircle, the cousinet will be the first arch-stone itself, or otherwise the arch must spring above the impost.

Cousinet is also employed to denote that part in the front of the Ionic capital, contained between the abacus and the echinus, or quarter-round. It is this which forms the horizontal fillet, or band, in common volutes, or the band and festoons in the Grecian Ionic, from which the volutes on each side of the column depend.

COVE, any kind of concave moulding, or the concavity of a vault.

Cove Bracketing, is the bracketing of any cove, but more generally understood to be that of the quadrantal cove, which is sometimes employed between the flat ceiling and the wall. *See* Bracketing.

COVED AND FLAT CEILING, one whose section is a portion or quadrant of a circle, springing from the walls of the room, and rising to a flat surface in the middle.

Coved and flat ceilings seem to be altogether of modern invention, and admit of some beauty in the decoration. It is a sort of compromise between the flat or horizontal ceiling, and the various forms of arched ones practised by the ancients. It does not require so much height as the latter mode, and has therefore been of considerable use in the finishing of modern apartments; but as its form is a compound, it wants both elegance of figure, and grandeur of design; nor does it admit of that beauty in decoration, that entire arched ceilings are susceptible of. The ancient forms were of three kinds, the cylindric arch, the dome, and the groin. We find no arches of any description in Grecian antiquity; but in the Roman edifices all the three varieties are to be found; and among other ceilings in the ruins of Balbec, the quadrantal coved ceiling, with the flat in the middle, may be distinctly traced, at least in length, if not in breadth. *See* Ceiling.

COVER, in slating, the part of the slate that is hid or covered; the other part exposed to view, is termed *the margin* of the slate.

Cover Way, in roofing, the recess or internal angle left in brickwork or masonry to receive the covering.

Covered Way, a passage covered over. The term Covered Way, or Covert Way, is also used in fortification to denote the piece of ground level with the field on the edge of the ditch, three or four fathoms broad, extending quite round the works towards the country. It has a parapet raised on a level, together with its banquettes and glacis. It is sometimes called the counterscarp.

Covering. *See* Roofing.

COVING, the exterior projecture over the ground-plan of buildings, made in an arched form with lath and plaster: it is not now in use. In former times, when the streets were very narrow, the upper rooms were made in part to jut over the wall, in order to give room.

Covings of a Fireplace, the inclined vertical parts on the sides, for contracting the opening, and throwing out the heat.

COW-HOUSE, a building where cows or other cattle are kept, in order to protect them from the severities of the weather. *See* Cattle Shed.

Cow-Yard, the enclosure in which cows are kept, to shelter them from the weather.

CRAB, an instrument used in masonry for raising large stones.

CRACKING OF BUILDINGS, those fissures occasioned by improper management in the foundation, or in carrying up the work. Cracks, so frequent in modern buildings, will for the most part be found to arise from unequal settlement, caused by insufficient foundations, from inadequate coverings to apertures, such as what are called French arches, or from the employment of improper or inferior materials, soft bricks, unseasoned timber and such like.

Cracking, in plastering, the fissures occasioned by an undue tempering or mixing of the materials, or by an unseasonable application.

CRADLE, or Coffer, in engineering, a large wooden trunk, open at top, with movable ends, large enough to receive a barge or vessel when floating on a canal, for the purpose of raising or lowering it to a higher or lower pond of the canal, by cranes or other means, without the use of a pond lock.

The term is also applied to the segment of a hollow cylinder formed of ribs and lattice, similar to centering, used by bricklayers and masons, for turning culverts and arches; the inside is smooth, and the exterior rough, for supporting and retaining the shape of the inverted arch of the lower half of the culvert in soft ground, particularly in quicksands and peaty places. A very slight cradle of this kind, will sometimes prevent the distortion or ultimate fall of a barrel culvert. This precaution should never be omitted in laying culverts under canals or roads, in soft grounds, as the falling of the culvert may prove of the greatest inconvenience.

Cradle-Vault, a word improperly applied to cylindric vaults.

CRADLING, the mass of timber-work disposed in arched or vaulted ceilings, for sustaining the lath and plaster. For the application of the various species of cradling, *see* the words Cylindric-Vault, Cove-Bracketing, Dome, Groin, and Niche. The compound term, *dishing-out*, is sometimes used by workmen, instead of cradling.

Cradling is also used for the rough timber-work for sustaining an entablature for a shop-front.

CRAMP, an iron instrument, about 4 feet long, with a screw at one end, and a movable shoulder or arm at the other, by which mortise and tenon work is forced together.

CRAMPERN, or Cramp-Iron, an iron bent at each extremity, towards the same side of the middle part, used to fasten stones together in a building.

When stones are required to be bound together with greater strength than that of mortar, a chain, or bar of iron, with different projecting nobs, is inserted in a cavity cut in the upper side of the course of stones across the joints, instead of single cramps across the joints of each two stones. Cramps are generally employed in works which require great solidity, as in the piers and abutments of bridges, and the voussoirs of large arches. They are also employed in uniting the stones of copings, and cornices, and generally any external work upon the upper surface, or between the beds of the stone. External work liable to the injuries of the weather,

ought to be cramped. The most secure manner of fixing cramps is to let them into the stones their whole thickness, and run them with lead ; but in slight works, it is sufficient to bed them in plaster, as is the practice in chimney-pieces. Iron is used in modern buildings, but the Romans, who were accustomed to employ cramps in the greatest profusion, used bronze, a material much more durable than iron, as it is not so liable to rust.

Bronze or copper is preferable to iron, not only on account of its own durability, but likewise because it is not so liable to destroy the masonry which it connects : the rust which accumulates round iron cramps, tends to rupture the masonry to a much greater extent, than the cramps to keep it together ; besides this, if placed near the surface, iron is sure to discolour it. In general work, if the masonry be well put together, there will be but little need of cramps, especially if the separate masses be of moderate size ; nor even if they be of small dimensions, is there any absolute necessity for their employment, as we may gather from the works of the ancients. Mr. Murphy instances the spires of Salisbury cathedral, and of the church of Batalha, Portugal, which though not more than seven inches in thickness, are for the most part connected without the aid of iron cramps. These observations apply with greater emphasis to wrought than to cast iron.

Sir Christopher Wren used a large cramp or chain below the springing of the dome of St. Paul's, in order to distribute the pressure equally. This architect, however, seems to have been fully aware of the caution requisite in the use of iron in stone buildings, for he observes in his *Parentalia*, "It has been observed in removing cramps from masonry at least four hundred years old, which were so bedded in mortar that all air was perfectly excluded, that the iron appeared as fresh as when it came from the forge. In cramping stones therefore, no iron should lie within nine inches of air if possible ; for air is the menstruum that consumes all materials. When for want of large stones the use of iron is requisite, care should be taken to exclude the air from it."

Copper, bronze, or gun-metal, form excellent and incorrosive substitutes for iron in cramping masonry ; they are more expensive at the first outlay, but will be found in reality more economical ; the first material may be mixed with a small portion of tin, which imparts to it greater durability.

The above objections to iron, do not hold good as regards brickwork ; the only inconvenience in this case arises from the stain with which the rust is apt to disfigure the work, if the iron be placed too near the facing.

CRAMPOONS, pieces of iron hooked at the ends, for drawing or pulling up timber, stones, &c.

CRANE-HOUSE, a house to shelter a crane ; it should be constructed of brick.

CREALS, a sort of jetties, or weir hedges, sometimes erected on the shores of rivers or the sea, for checking the force of the tide in particular places, and occasioning a deposit of filth or mud in place of the constant wear and encroachment of the water upon the land. Smeaton's *Reports*, i. p. 4.

CREASING, *Tile*. See TILE-CREASING.

CREDENCE, a shelf or small table by the side of a Christian altar, on which the sacred elements are placed previous to consecration. Sometimes the credence is simply a shelf in the niche above the piscina, but at other times a separate table. At the church of S. Cross is a beautiful specimen, rectangular in plan, having its front decorated with panels, and the stone slab supported above a cornice enriched with flowers, it is fixed in a corner so that only two sides are exposed ; at Fyfield, Berks, is another specimen, semi-octagonal in plan, supported on a stem of similar plan, but of smaller dimensions ; the sides are panelled all the way up.

CRENELLE, the embrasure of a battlement, sometimes applied to the whole battlement, as also to the loopholes and other small apertures in the wall of a fortress, through which missiles were discharged.

CRESCENT, an ornament used by the Mahometans in their mosques.

CRESCENT, a series of buildings, disposed in the arc of a circle, which is either the half circumference, or the arc of a segment less than the half.

CRESILLA, a Grecian sculptrix, who chiselled seven statues of the Amazons, for the temple of Diana at Ephesus, and was accounted the third in merit among the numerous competitors who vied in decorating that famed edifice—being only inferior to Polycletus and Phidias.

CRESSET, an open metal frame or cage, used to contain a light or beacon-fire.

CREST, the ornamental finishing at the summit of a structure, consisting of battlements, open tracery, finials and crockets, or even plain coping.

CREST-TILES, tiles placed along the ridge of a roof overlapping on both sides like a saddle ; they are sometimes plain, and at others ornamented, moulded in the form of battlements, Tudor-flowers, crockets, leaves, &c.

CREUX (from the French), a term in sculpture, implying a hollow, out of which anything has been scooped ; and hence it has been used to denote that kind of sculpture and graving, where the lines and figures are cut and formed within the surface carved or engraved upon.

There is no word in the English language that answers to this idea, and hence the necessity of adopting the term. It is opposed to the word *relievo*, where the lines and figures are prominent, and project without the surface.

CRIB, the rack or manger of a stable, or the stall or cabin of an ox. It is also used for any small habitation, as a cottage.

CROCKET (from the French, *croc*, a hook, or fork) an ornament used to decorate or finish the raking arrises of parts of Gothic buildings, such as spires, pinnacles, gables, canopies, &c. ; consisting of projecting leaves, flowers, or knops of foliage, and terminating usually in a larger ornament or bunch of flowers or leaves at the summit, called a finial. Sometimes they are used in vertical lines, as at the cathedral, Lincoln, where they run up the mullions of the tower window. Crockets of the Early English style are often simple trefoil leaves, and sometimes bunches of such leaves, placed at considerable intervals, and curled backwards, in a similar manner to the head of a bishop's pastoral staff: early specimens are to be seen at Salisbury and Wells cathedrals, but the simplest example exists at Lincoln, which exhibits a simple curve, curling round downwards. In the Decorated period, the leaves were usually continued for some distance attached to the moulding, and curled upwards towards the extremity, sometimes the extreme point was turned up ; a similar form prevailed in the Perpendicular style, but they are sometimes merely flat square leaves united to the moulding by the stalk and one edge. In some cases we meet with animals in the place of crockets, as on the flying buttresses of Henry VII.'s chapel, Westminster, and the gables of the hall at Hampton Court; on the tomb of Archbishop Kempe, Canterbury, we find swans, and on that of Bishop Bingham, Salisbury, angels are used for the same purpose.

CROISSANTE CROIX, having a crescent or halfmoon, fixed to each end thereof.

CROKET. *See* CROCKET.

CRONACA, SIMONE, a Florentine architect, born in the year 1454. This artist travelled to Rome, and other cities of Italy, in order to take accurate admeasurements of the ancient edifices. When he returned to Florence, he acquired considerable reputation, and was employed to finish the Palazzo Strozzi, which was begun by Benedetto da Maiano. Among his other works in this city, are the sacristy of the church of Santo Spirito, and the church of S. Francesco del Offervanza, at S. Miniato, in the suburbs of the city. He died in the year 1509, and was buried in the church of S. Ambrozio Vasari.

CROOKED LINE, one that cannot have a tangent on any point to the two adjacent parts of the line on each side of the point of contact.

CROSETTES, in the decorations of apertures, the trusses or consoles on the flanks of the architrave, under the cornice; they are otherwise named *ears*, *elbows*, *ancones*, or *prothyrides*.

CROSIER, a bishop's staff; it was originally a plain rod with a cross-head at its summit, and subsequently with a curved top similar to a shepherd's crook. Crosiers were sometimes of a very costly description, being formed of gold or silver, engraved, enamelled, and inlaid with jewels and precious stones. A good specimen is that of William of Wykeham, preserved at New College, Oxford. The crosier of an archbishop is surmounted by a cross, and that of a primate or patriarch by a double cross.

CROSS, a figure consisting of four branches, at right angles to each other; or a geometrical figure, consisting of five rectangles, each side of one angle being common with one side of each the other four.

The cross, as the most prevalent symbol of the Christian religion, was often introduced into their architecture. Their churches, more especially the larger ones, were frequently built on a cross plan, and were decorated internally and externally with this symbol; crosses of a highly decorative character and beautiful design were often affixed to the apex of gables, and in the interior were depicted on the walls; a large ornamental cross, usually of wood, called the rood, was set above the screen, which separates nave and chancel, and a small one of metal, enriched with jewels, &c., on the altar.

There are two kinds of cruciform plans used in ecclesiastical buildings; one, in which all the five rectangles are equal; or, in which each of the four wings is equal to the middle part formed by the intersection, is called a *Greek cross*. The other, in which only two opposite wings are equal, and in which the other two are unequal, and the three rectangles in the direction of the unequal parts of greater length than the three parts in the direction of the equal parts, is called a *Latin cross*, the middle part in each direction being common.

Stone crosses were erected in front of the entrance to the church, and these consisted of a tall shaft raised on one or more steps, and surmounted by an ornamental cross; the shaft was usually of a simple character, but sometimes enriched with sculpture. Besides these, there were boundary, memorial, sepulchral, preaching, and market crosses.

Boundary-crosses were of a very simple character, being usually merely upright stones ornamented with some simple sculpture; memorial crosses were of a like plain description, there is a specimen at Blore-heath, Staffordshire. The crosses erected by king Edward I. at the places where the corpse of his queen Eleanor was rested during its progress from Lincolnshire to Westminster for interment, would probably come under this head, but if so, they are of a very different description to the majority. Out of fifteen of these originally existing, only three now remain, at Geddington, Northampton, and Waltham: of those now destroyed, five are known to have been erected at the following places, Lincoln, Stamford, Dunstable, St. Alban's, and Charing. They were very elaborate structures, consisting of several stories of multangular plans, each story being somewhat smaller than the one below it, so as to give the erection a pyramidal form, having the apex surmounted by a cross, and the whole enriched with sculpture, statuary, &c; that at Waltham consists of three stories, and is hexagonal in plan, the lower story is richly panelled, the second canopied, containing statues of the queen, the third panelled, similarly to the lowest, and the whole finished at the top with a decorative cross.

The preaching-cross was a covered pulpit usually erected in the vicinity of a church, the most noted is that of St. Paul, London, which was an erection of wood raised on steps, and covered with a canopy; it was octagonal in plan, closed in on all sides, with the exception of the entrance and the aperture, through which the preacher addressed the people. Specimens of this class exist at Hereford, Iron Acton, Gloucestershire, and Holbeach, Lincolnshire.

Market-crosses seem to have been originally of a similar form to those of Queen Eleanor, but having open arches at the sides in the lowest story. In the later and more general form, the plan of the basement was considerably extended, so as to present a space of considerable size covered with a vaulted roof, and having a central pillar or pier to support the superstructure, which at the same time was much reduced in height; the shape of the original plan was preserved, the only difference being in its size; thus the market-cross at Leighton Buzzard, Bedfordshire, is pentagonal, that at Salisbury, hexagonal, and that at Malmsbury, which is a beautiful specimen, hexagonal. Other market-crosses exist at Winchester, Cheddar, and Chichester, and there were two excellent ones at Coventry and Glastonbury. They served to shelter the people attending market from heat and rain.

The cross at Chichester is the most beautiful specimen of the kind. It is supported on eight buttresses and a central column, from which issue a number of ribs dividing the vaulted roof: between the buttresses are eight arches moulded, and surmounted by an ogee canopy, which is crocketed, the finial supporting a pinnacle; the spandrels of the canopy are richly panelled, as are also the walls above, the whole being finished by a panelled parapet. The buttresses terminate in crocketed pinnacles. The structure is covered externally by an ogee cupola, crocketed ribs springing from each of the buttresses at the angles, and the whole is surmounted by a small octangular turret pierced with eight arches, and otherwise elaborately ornamented.

Crosses of a simple character were originally erected at the entrance of towns and villages, at the intersection of cross-roads and sides of highways, to arrest the attention of travellers, and excite their devotion.

CROSS-BANDED, in hand-railing, is when a veneer is laid upon the upper side of the rail, with the grain of the wood crossing that of the rail, and the extension of the veneer in the direction of its fibres less than the breadth of the rail.

CROSS GARNETS, hinges, with a long strap, which is fixed to the closure of the aperture, and with a cross part on the other side of the knuckle, which is fastened to the joint.

CROSS-GRAINED STUFF, wood with its fibres in contrary directions to the surface, and which therefore cannot be made perfectly smooth by the operation of the plane, without either turning the plane or the stuff. This most frequently arises from a twisted disposition of the fibres in the act of growing.

Cross Multiplication, a term used by artificers for the peculiar arithmetical process employed in the mensuration of their work. Cross multiplication and duodecimals are generally confounded together as being synonymous expressions; but the order of performing their operations is materially different. In cross multiplication, the parts are actually multiplied *crosswise*, as well as in direct order, and the terms of each factor are confined to feet and inches; whereas, in duodecimals, the terms of each of the factors are not confined to number, and the parts are multiplied in the order of common multiplication.

The rule in cross multiplication is as follows: Write the given numbers, as in addition. The sum of the products of the alternate parts, and the product of each pair of parts in each denomination, will be the product of the whole. It must be remembered, that

Feet multiplied by feet give feet.
Feet multiplied by inches give inches.
Feet multiplied by seconds give seconds.
Inches multiplied by inches give seconds.

The method of performing the operation will be seen in the following examples.—What is the area of a board, the length of which is 25 feet 11 inches, and the breadth 23 feet 7 inches?

ft.	in.			
25	11			
23	7			
0	6	5	=	7×11
14	7		=	7×25
21	1		=	23×11
575			=	23×25
611	2	5		

Required the product of 58 feet 9 inches, by 36 feet 6 inches.

ft.	in.			
58	9			
36	6			
0	4	6	=	6×9
29			=	58×6
27			=	36×9
2088			=	58×36
2144	4	6		

The following method is another form of cross multiplication, discovered by Mr. P. Nicholson, in which side operations are unnecessary, and consequently, as a part of the work, must either be wrought on the margin, as above, or in the mind: the work, by the method proposed, will be shorter than the above, or less liable to mistake, if the side operations be not used. The rule is thus:

Multiply the inches together, and the product is seconds; divide the product by 12, if so divisible, the quotient is inches, and the remainder seconds; then, placing the feet and the inches in their respective order, one after the other, set the products of the two cross parts in inches, under the inches of the former quotient; add the three numbers together, and divide their sum by 12, the quotient will be feet, and the remainder inches; multiply the feet of the multiplier by the feet of the multiplicand, and place the products under the feet of the last division, then the sum of these products will be the number of feet in the whole contents, and the remainders of inches and seconds, if any, the parts which are required to complete the whole product. We shall take the two former examples, and the one method will be the best proof of the truth of the other.

First Example.			Second Example.		
ft.	in.		ft.	in.	
25	11		58	9	
23	7		36	6	
6	5		4	6	
175			348		
253			324		
12)434			12)676		
36	2		56	4	
75			348		
50			174		
611	2	5	2144	4	6

By this means, the whole is performed in one operation, without laying any stress on the memory, and will therefore be particularly useful to those who have not sufficient practice to fix the products and quotients of small numbers on their memory: and it is the shortest method of the two, if the number of marginal figures be counted into the work of the former method of operation.

In duodecimals the process is as follows: beginning with the last term, or the farthest from the left-hand in the multiplier, multiply by it each term of the multiplicand from the right-hand to the left, carrying one for every twelve to each successive product, but the denominations must not be carried farther than the place of feet; again, multiply all the terms of the multiplicand, by each successive term towards the left of the multiplier; then place the products one under the other, with the first term of every product on the left, under the second term of the product of the horizontal row immediately above; then add the similar denominations of each product: the sum will be the whole product. Observe, in the first place, to put the highest denomination, viz., the feet, under the first term on the left of the multiplicand, and the terms of the product under each respective term of the multiplicand will be of the same denomination with each other.

Example.—Suppose, again, it were required to multiply 25 feet 11 inches by 23 feet 7 inches, by duodecimals.

25	11	
	23	7
15	1	5
596	1	
611	2	5

$11 \times 7 = 77$

6 5

$25 \times 7 = 175$

181

15 1 $= \frac{181}{12}$

$11 \times 23 = 253$

21 1 $= \frac{253}{12}$

$25 \times 3 = 75$

$25 \times 20 = 500$

596

Cross multiplication is much better adapted to finding the superficial contents of a piece of work, where there are only

two terms in each factor, and where the feet of the multiplier run to a high number, as well as the feet of the multiplicand, and more particularly the second mode of cross multiplication; as in duodecimals, the calculator must either have a very good memory to require no marginal work, or otherwise the quantity of marginal operations will exceed that of the principal work. Artificers and measurers never take any account of denominations less than inches, except in glazier's work, and hence cross multiplication is almost the only useful method of finding the contents; but where more denominations are concerned, recourse must be had to duodecimals or decimals, as when the terms of each factor are more than two, cross multiplication cannot be applied.

When the terms of the multiplier are under 10, the operation will be exceedingly easy, as the following example will show.

Example.—Multiply 8 feet, 3 inches, 5 seconds, and 7 thirds, by 5 feet, 4 inches, 9 seconds, and 6 thirds.

ft.	in.	ii	iii			
8	3	5	7			
			5	4	9	6
		4	1	8	9	6
	6	2	7	2	3	
2	9	1	10	4		
41	5	3	11			
44	9	0	6	3	0	6

It will be perceived that there is a great difference between cross multiplication and duodecimals, and the purposes to which each may be most advantageously applied; but the reader who wishes for farther information on this subject, may have recourse to the articles DECIMALS, DUODECIMALS, and PRACTICE.

CROSS SPRINGERS, in groins of the pointed style, are the ribs that spring from one diagonal pier to the other.

CROSS VAULTING, a vault formed by the intersection of two or more simple vaults. When each of the simple vaults rises from the same level to the same height, the cross vaulting is denominated *a groin;* but when one of two simple vaults, in cross vaulting, is below the other, the intersection s simply demominated an *arch* of that particular species which expresses both the simple arches; thus if one cylinder pierce another of greater altitude, the arch so formed is called *a cylindro-cylindric arch;* and if the portion of a cylinder pierce a sphere of greater altitude than the cylinder, the arch is denominated *a sphero-cylindric arch:* and thus, for any other species of arch whatever, the part of the qualifying word which ends in *o*, denominates the simple vault which has the greater altitude, and the succeeding part the other of less altitude.

CROUDE, a subterraneous vault or crypt.

CROW, a bar of iron, used in bricklaying and quarrying.

CROWN, in architecture, the uppermost member of a cornice, comprehending the corona and its superior members.

CROWN OF AN ARCH, the most elevated line or point that can be taken on its surface.

CROWN, in geometry, a plane ring, the surface being contained between the circumferences of two concentric circles.

The area will be found by multiplying half the sum of the two circumferences by its breadth; for it is easy to conceive, that if radiating lines be equidistantly drawn indefinitely near each other, the whole will be divided into truncated isosceles triangles, or trapezoids, whose opposite angles are equal to two right angles; then the broad and narrow ends being placed alternately in a straight line, and the sides in contiguity with each other, the whole will form a rectangle, whose length is equal to the half sum of the two circumferences, and the breadth that of the ring; for all the middle breadths are in one straight line, equal to the length of the rectangle.

Example.—Suppose the greater circumference of a crown to be 24 feet 8 inches, and the lesser 21 feet 6 inches, and the breadth 2 feet 9 inches, required the superficial content?

By cross multiplication.

	ft.	in.	
	24	8	
	21	6	
2)	46	2	
	23	1	
	2	9	
		0	9
	207		
	2		
12)	209		
	17	5	
	46		
	63	5	9

By decimals.

$24.666 = 24\frac{2}{3}$
$21.5 \quad = 21\frac{1}{2}$

2) 46.166

23.083
2.75 $= 2\frac{3}{4}$

115415
161581
46166

63.47825 content in ft. & dec.
12

5.73900 inches
12

8.868 seconds.

CROWN GLASS, the finest sort of window-glass. See GLASS.

CROWN-POST, in truss-roofing, the truss-post, which is placed between a pair of principal rafters, or depending from the summit of the principals, in order to support braces or struts for sustaining the intermediate bearing of the principals, or keeping them from being bent by the weight of the covering. It is otherwise called *king-post* and *joggle-post.* *See* POST and TRUSS-POST.

CROWNING, in general, the part that terminates any piece of architecture. Thus the cornice, a pediment, acroteria, &c., are called *crownings.*

CRUCIFIX, a cross with a figure or representation of S. Saviour crucified, affixed to it.

CRYPT, according to Vitruvius, the under part of a building, answering nearly to our cellar.

The term is more particularly applied to a vaulted apartment beneath a church, either entirely, or partly under ground. Crypts owe their origin to the circumstance of the early Christians being compelled, for the sake of secresy and concealment, to perform their sacred services in caves and subterraneous places, some of which are still pointed out at Rome. Crypts are not unfrequent, especially under large churches, they seldom, however, extend the whole length of the church, being usually confined to the choir or chancel, and sometimes not extending so far as this: they are usually low and massive, of an earlier and plainer style than the superstructure. Many crypts are claimed as belonging to the Saxon style, as those of Lastingham Church, Yorkshire; S. Peter's, Oxford; Repton Church, Derbyshire; and portions of those of many of our cathedrals.

Crypts were formerly used for service, and accordingly are provided with altars and other furniture requisite for the purpose. The most extensive building of this kind is that under Canterbury Cathedral, which is thus described by Mr. Britton:

"Like those at Winchester, the crypts of Canterbury Cathedral appear to have been built at different times. Their eastern termination is semicircular; which form has been also observed in the small lateral chapels. The interior length of the Canterbury crypts is 286 feet 6 inches. The age of the oldest part has long been the subject of controversy; but from its similarity to the crypt at Oxford, it may be regarded as contemporaneous with that; it was most probably the work of Lafranc, about A.D. 1080. The larger, or western crypt, is divided into a nave and four aisles, by two rows of massive piers, and by a double range of small columns; whilst the piers and walls of the aisles have semi-columns to support the vaulting. Branching laterally from each aisle is a vault or chapel; that on the south side, the vaulting of which is adorned with many ribs, bears evident marks of innovation, and is supposed to have been converted into a chantry chapel by Edward the Black Prince, whose arms are seen among its ornaments. Towards the eastern end of this crypt was a chapel, inclosed with screen-work, and dedicated to the Holy Virgin. The crypt under the Trinity Chapel, or east end of the cathedral, is singular in form and character. Its plan assumes the figure of an horse shoe; and is divided into a nave and aisles by a series of eight piers, each formed of two columns, engaged about one-quarter of their diameter, supporting four semicircular and five pointed arches, their respective forms being influenced by the width of the intercolumniations. In its central division, or nave, are two small insulated shafts, with large capitals and bases to support the ribbed groining, which is distinguished from that of the western crypt by cross-springers and bold mouldings. At the eastern extremity is a small vaulted chamber, forming the termination of these interesting apartments."

Amongst the smaller examples, may be noticed that of Hythe, Kent, and those of Repton, and St. Peter's in the East, Oxford, before-mentioned.

Crypto-Porticus, a subterraneous passage, as the original word implies. If we may judge (says Winckelman) from the remains of antique edifices, particularly those of the Villa Adriani, at Tivoli, we might be led to believe that the ancients preferred darkness to light: for, in fact, we find scarcely any chamber or vault among these ruined edifices, which has any appearance of windows. It seems probable, that in some, the light was only admitted through an opening in the middle of the vault, but as the vaults are generally fallen, this point cannot be ascertained. The inhabitants of Italy are naturally attached to the shade and coolness of half-lighted apartments. The long galleries of the Villa Adriani, which are undoubtedly crypto-porticos, receive a feeble light at each end, from embracing near the ceiling.

The term crypto-porticus was, however, applied, in course of time, to apartments similar to our galleries.

We find, in Pliny's description of his house at Laurentium, that the crypto-porticus had windows on each side, looking towards the sea, and upon his garden; also other windows over these. When the weather was cold, they were shut on the side that sheltered them from the wind, but in warm and serene weather they were all set wide open.

CUBATURE, or Cubation, of a solid, the solid contents according to any common measure, as a solid inch, foot, yard, &c., which is called the measuring unit. The cubature is the same in respect to the contents of a solid, as the quadrature is in respect of a superficies.

There is one general rule that will apply to finding the cubation of nearly all the regular solids as entire bodies, or to their frustums or segments, viz. "to four times the area of the middle section add the area of each end; multiply one-sixth of this sum (which is the mean area) by the distance between the ends, and the product will give the content of the solid."

This rule has been applied to three particular cases, viz., in the prismoid, cask measuring, and the frustum of the hyperboloid; it has also been demonstrated rather as a theoretical curiosity, than as a practical rule, at the end of Dr. Hutton's Mensuration, applied to solids generated from conic sections.

This rule, however, applies to solids in general, and comprehends the whole of mensuration in its principle; though such an extension has never been noticed by any writer on the subject, yet it cannot fail to be of the utmost use in assisting the memory; for when particular rules are forgotten, this general one may be easily remembered. It will apply with accuracy to prisms, pyramids, prismoids, cones, conoids, cuneoids, spheres, spheroids, and to all their segments and frustums, cut by planes parallel to their axes.

Some may object, however, by saying it is not easy to come at the dimensions of the middle section; but in straight solids these will be very readily ascertained, by taking half the sum of the two ends; in complete spheres and spheroids, the middle dimension is absolutely given. In the hyperboloid and its frustums, the dimensions of the middle section is much easier obtained than either the transverse or conjugate diameters, one of which, or both, it would otherwise be necessary to have. In the paraboloid and its frustums, the middle area is half the sum of the areas of the two ends. The reader who is desirous of seeing the application of this general rule, may consult the article Solid.

CUBE (from κυβος, *tessera*, die) a solid, bounded by six squares; it is otherwise called a *hexahedron*, from its six sides. Its simple properties are, that its sides are all equal and at right angles with each other: it has also its opposite sides parallel to each other. The cube may be conceived to be generated by a square figure along a right line, of equal length to the side of the square, and perpendicular to the plane. From its construction, it is evident that all sections of the solid, parallel to any side, are equal.

The envelope, rete, or net, may be thus constructed: Draw two lines, A D and A B, at a right angle with each other; make A B equal to the side of one of the squares, and A D equal to four times A B, marking the points of division, E G I; draw B C parallel to A D, and D C parallel to A B, parallel to which also draw E F, G H, I K, cutting B C at F, H, K: produce E F and G H on both sides, to L and M on the one side, and N and O on the other, making E L, G M, F N, H O, each equal to E F, and join L M and N O; this will complete the envelope required.

Hence the superficies of a cube is found by multiplying the area of one of its sides by 6.

The solidity of a cube is found by multiplying the area of one of its squares by one of the lineal sides of a square. Hence if one lineal side be 10, the solidity will be 1,000; and if 12, it will be 1728; wherefore a cubic perch contains 1,000 cubic feet, and a cubic foot of 1728 cubic inches.

Cubes are to one another in the triplicate ratio of their lineal sides.

CUBIC NUMBER, one which arises by multiplying two equal numbers, and the product again by another equal number: thus, $12 \times 12 = 144$, and $144 \times 12 = 1728$.

CUBICLE, a bed-chamber. *See* Chamber, and the next word.

CUBICULUM, among the Romans, a bed-chamber. This name was also given to the balcony or logia, in which the emperors were placed at the public games.

CUBIT, a lineal measure used by the ancients, particularly by the Hebrews, taken from that part of a man's arm between

the elbow and tip of the hand. The English cubit may be calculated at 18 inches, the Roman at 17.406, and the Hebrew at 21.888 inches.

CUL-DE-FOUR, or CU-DE-FOUR, a sort of low spherical vault, ovenlike. This is the definition generally given; but this term, as also the following, are altogether void of specific meaning. As they define nothing, we have only retained them as being found in all large encyclopædias and builder's dictionaries, in order that our architectural nomenclature should not be thought deficient. What is meant by a low spherical roof? Is it a segment less than a hemisphere? Where is the similarity between an oven and a spherical surface? Is not the latter definite, but the former indefinite?

CUL-DE-FOUR OF A NICHE, denotes the arched roofs of a niche on a circular plan. These two definitions are of French origin.

There may be many forms of arched roofs or heads, on a circular plan; however, the probability is, that it is either spherical or spheroidal, terms perfectly specific, unless it be in the quantity or portion of the surface employed.

CULMEN, in ancient Roman carpentry, answers to what we denominate the ridge-piece of a roof.

CULVERT, an arched drain for conveying rills and brooks of water under canals or roads, from the higher level on one side, to the lower level on the other side of the canal or road.

They are also employed for discharging the rain-water out of hollows on the upper side of a canal. When such a drain or water-passage has a descent, so as to make it lower in the middle, it is said to be *broken-backed*.

CUNEUS, one of the mechanical powers. *See* WEDGE.

CUNEUS, in Roman antiquity, that part of the theatre where the spectators sat, which was so named on account of its resemblance to a wedge. This form became necessary on account of the elliptic figure of the edifice, and of the staircases and doors, which were fixed in radial directions, and divided the seats into wedge-form compartments.

CUPBOARD, a recess in a wall, fitted up with shelves, to contain articles when not in use.

CUPOLA, a roof or vault, rising in a circular or elliptic curve, from a circular, elliptic, or polygonal plan, to its summit, with its concavity towards the plan, the interior or exterior surfaces being such, that every horizontal section, whether the one or the other, are similar figures. A cupola is otherwise termed *tholus*, or *dome*. *See* the latter word for its history and properties.

CURB, in a general sense, signifies a check or restraint.

CURB FOR BRICK STEPS, a timber nosing generally of oak, employed not only to prevent the steps from wearing, but also from being dislocated or put out of their places. When the steps are made to return, the curb also returns, but when they profile against a wall, the ends of the curb or nosing-pieces, house at each end into the wall.

CURB PLATE, a circular continued plate, either scarfed together, or made in two or more thicknesses. The wall-plate of a circular or elliptically ribbed dome, is termed *a curb plate*, as also the horizontal rib at the top, on which the vertical ribs terminate; likewise the plate of a skylight or a circular frame for a well.

CURB PLATE, also the horizontal piece of timber supported by the upper ends of the lower rafters, for receiving the feet of the upper rafters, in a curb roof.

CURB RAFTERS, the upper rafters on both sides of a curb roof.

CURB ROOF, a roof formed of four contiguous planes, of which each two have an external inclination, the ridge being the line of concourse of the two middle planes, and the highest of the three lines of concourse. This construction is frequently denominated *a Mansard roof*, Mansard being the name of its inventor. It is very well adapted to a house surmounted by a parapet, so high as to cover the lower plane of the roof, as it gives a free or uninterrupted space from the level of its base to that of the summit of each lower plane, or to the base of the two upper planes. In curb roofing, there is no danger of springing the walls by lateral pressure, for the distance between the base of the lower sides and the base of the upper sides, being sufficiently high for head-room, ties can always be fixed in these two situations, which will prevent all danger. Indeed, if the four sides of the roof be properly balanced, the space may be made a complete void to the very ridge, or the upper part may be thrown into a cylindric arch.

A curb roof has great advantages over a common roof, on account of the lower rafters pitching almost perpendicularly to their bases, and forming very nearly a continuation of the walls: whereas, in common roofs, the great inclination of the sides, and the quantity of head-room required, diminishes the space for lodging, in the breadth of the building; in most cases there will be a loss of about 15 or 16 feet at least, and consequently, in small houses, no lodging-room whatever.

Curb roofs are generally lighted from dormer windows in the lower side.

The following contains the theory and practice of curb roofing, which is perhaps one of the most interesting parts in the science of carpentry:

Proposition I. *Figure* 1. The position of several rafters, AB, BC, CD, DE, &c., being given in a vertical plane, and movable about the angular points B, C, D, E, &c., while the points A and G remain stationary; it is required to find the proportion of the forces at the angles, so that the rafters may be kept in equilibrio.

Through the points B, C, D, &c., draw the vertical lines Bi, Cm, Dp, &c., the direction of the forces; make Bi of any indefinite length, and complete the parallelogram $Bhik$; make Cl equal Bk, and complete the parallelogram $Clmn$. Proceed in this manner with all the remaining parallelograms, making the two opposite forces in the direction of each rafter equal, and the diagonals Bi, Cm, Dp, &c., will represent the forces required, as is evident from the construction. Then, to find the proportion of the weights upon any two angles, the sine of any angle is the same with the sine of its supplement; therefore, the sine of the angle ABC is the same as the sine of Bki, and the sine of BCD the same as the sine of Cmn; likewise, the sine of the angle Cml is equal to the sine of the alternate angle mCn, and the sine of the angle Dpo is equal to the sine of the angle pDq; moreover, the sine of the angle iBk is equal to the sine of the angle mCl, and the sine of the angle mCn is equal to the sine of the angle pDo, and so on: then, because the sides of the triangle are the same as the sines of their opposite angles, it will be by trigonometry,

$$Bi : Bk, \text{ or } Cl :: \text{s.}Bki, \text{ or } ABC : \text{s.}Bik, \text{ or } iBh.$$
$$Cl : lm, \text{ or } Do :: \text{s.}Cml, \text{ or } mCn : \text{s.}mCl, \text{ or } iBk.$$
$$Do : op, \text{ or } Er :: \text{s.}Dpo, \text{ or } pDq : \text{s.}pDo, \text{ or } mCn.$$
$$Er : sr, \text{ or } Fu :: \text{s.}Esr, \text{ or } vFu : \text{s.}Esr, \text{ or } pDq.$$
$$Fu : Fv :: \text{s.}Fvu, \text{ or } vFw : \text{s.}vuF, \text{ or } EFG.$$

$$\text{Therefore, } Bi : Fv :: \text{s.}ABC \times \text{s.}vFu \times \text{s.}vFw : \text{s.}iBh \times \text{s}iBk \times \text{s.}EFG.$$

$$\text{Therefore, } Bi : Fv :: \frac{\text{s.}ABC}{\text{s.}iBh \times \text{s.}iBk} : \frac{\text{s.}EFG}{\text{s.}vFu \times \text{s.}vFw}.$$

That is, the weights on any two angles are as the sines of these angles directly, and reciprocally as the product of the sines of the two parts of these angles formed by the vertical lines.

Corollary 1. Hence the weights on any two angles are as the sines of the angles directly, and as the produce of the co-sines of the angles of elevation reciprocally. For, draw B H perpendicular to B i, and produce i B and A B to I and K, then will the angle K B I, equal the angle h B i, be the complement of the angle H B K, viz., the complement of the angle of elevation of the rafter A B above the horizon; and because C B I is the supplement of C B i, the angles C B I and C B i have the same sine, and the angle C B I is the complement of the angle H B C, viz. the angle of elevation of the rafter B C.

Corollary 2. Hence also the weights on any two angles are as the sines of the angles directly, and as the products of the secants of elevation jointly; for the secants of any two angles are reciprocally as the co-sines of these angles.

Corollary 3. The force which any rafter makes in its own direction, is as the secant of its elevation. For, make A P equal to B h, draw the lines P N, k H, n L, &c., parallel to the vertical lines B i, C m, &c., and draw A N, B H, C L, &c., parallel to the horizon; then because the angles N A P, H B k, L C n, &c., are the angles of elevation, and A N, B H, C L, &c., are all equal, if A N, B H, C L, &c., be considered as radii, A P, B k, C n, &c., are the secants of elevation, and also represent the forces on the rafters.

Corollary 4. Hence the horizontal pressures at A and C are equal; for all the perpendiculars drawn from the opposite angles of each parallelogram to meet the vertical diagonal, are all equal.

Corollary 5. Hence, if the position of any two rafters, and the proportion of the weights be given, the position of the remaining rafters may be determined.

Corollary 6. If the vertical line S D V be drawn, the horizontal line A V G and the lines A S, A R, A Q, A T, &c. be drawn parallel to the rafters A B, B C, C D, D E, &c. meeting the vertical lines in S, R, Q, T; then will A S, A R, A Q, A T, represent the forces, and S R, R Q, Q T, the forces upon the angles; for A S, A R, A Q, A T, &c. are the secants of the elevation, and the triangles A S R, A R Q, A Q T, are all similar to the triangles h B i, l C m, o D p, &c.

Corollary 7. In every roof kept in equilibrio by the weight of the rafters, if U, V, W, &c. be the centres of gravity of the rafters, and also represent their weights, then the weight pressing vertically on B, will be

$$\frac{AU \times U}{AB} + \frac{VC \times V}{BC}, \text{ and the weight on } C = \frac{VB \times V}{BC}$$

$$+ \frac{WD \times W}{CD}, \text{ and so on. Hence } \frac{AU \times U}{AB} + \frac{VC \times V}{BC}$$

$$: \frac{VB \times V}{BC} + \frac{WD \times W}{CD} : : \quad \frac{S.ABC}{S.hBi \times S.iBK} : \frac{S.BCD}{S.lcm \times S.mcn}$$

Corollary 8. Hence, if the rafters be prismatic figures, the weights on the angles B, C, D, &c. will be respectively as A B+B C, B C+C D, C D+D E, and so on.

Proposition II. *Figure* 2. Given, the vertical angle of a roof, and the proportion of the rafters on each side; to describe the roof of a given width, so that it shall be equilibrio.

Let the proportion of the rafters from the bottom, upwards, be as 4, 3, 2:

Then $4+3=7$ represents the weight on G.
$3+2=5$ represents the weight on H.
and $2+2=4$ represents the weight on I.

Now let F B E be half the given angle, produce E B through C to D, draw F A M perpendicular to E D cutting E D at A; make A E equal to A B, and join E F; let B E represent the weight on the vertical angle: E B, B C, C D, to one another as 4, 5, 7; join F D, F C, F E; from any scale of equal parts make F G=7; draw G H parallel to F C, equal to 5 parts, and H I parallel to F B, equal to 4 parts, and the contiguousl ines F G, G B, H I, will be similar to the half roof. The other half will be found by drawing the vertical line I N, and ordinates perpendicular thereto, from the points G H, to L and K, and making the distances on both sides of I N equal. This figure may be reduced or enlarged to any given width, by making a similar figure upon a given line.

Proposition III. *Figure* 3. The angular points at the meeting of every two rafters of a roof in equilibrio, by equal weights hung at the angles, in directions equidistant from each other, are in the curve of a parabola.

Let A B C D E, &c. be kept in equilibrio, by equal weights suspended at the angular points B, C, D, E, &c., in the equidistant directions B F, C G, D H, E I, &c., the points A, B, C, D, E, &c., are in the curve of a parabola.

For, let the lines B F, C G, D H, and E I, meet A N at F, G, H, I: draw A K parallel to D E, A L parallel to C D, and A M parallel to B C, cutting F B at K, L, M. Draw B Q, C P, D O, parallel to A N, cutting the middle line I E at Q, P, O.

Then, because that the weights on the angles are equal, F K, K L, L M, M B, are as the numbers 1, 2, 2, 2, therefore, F K, F L, F M, F B, are as the odd numbers 1, 3, 5, 7; but because of the equidistant lines B F, C G, D H, and parallels D O, C P, B Q, the triangles A F K, A F L, A F M, are respectively equal and similar to the triangles D O E, C S D, B R C; therefore F K is equal to O E, F L equal to S D equal to O P, F M equal to R C equal to P Q, and lastly, B F is equal to Q I; therefore E O, O P, P Q, Q I, are to one another as the numbers 1, 3, 5, 7, and E O, E P, E Q, E I, are as the square numbers 1, 4, 8, 16, but the lines O D, P C, Q B, are to one another as 1, 2, 3, 4; therefore the abscissas E O, E P, E Q, E I, are as the squares of the ordinates O D, P C, Q B, and the points A, B, C, D, E, are in the curve of a parabola.

In the same manner it may be shown that this is the case, whatever be the number of ordinates.

Corollary.—Hence a roof of this construction may be described to any given height and vertical angle, or to a given width and height with any number of rafters on each side.

Example.—To describe a roof with any given number of rafters on each side, of a given width and height, so that all the weights suspended from the angular points of the rafters in vertical equidistant lines, may keep the rafters in equilibrio.

Figure 3.—Let there be four rafters on each side, let I N be half the width, and I E, the height. Draw N T and E T parallel to I E and I N; divide N T into four equal parts, N f, f e, e d, d T, and draw d g E, e h E, f i E: likewise divide I N into four equal parts, I c, c b, b a, a N, and draw c g, b h, a i, parallel to I E. Join E g, g h, h i, i N, and these lines will be the rafters of half the roof required. For the demonstration, see the article CONIC SECTIONS.

Proposition IV. *Figure* 4.—Suppose it were required to construct a curb roof to have the bottom rafter to the upper rafter as 2 to 3, to a given vertical angle at the top, and a given width A B.

Now the weight on the upper angle is to the weight on the lower angle, as $\frac{2\,HI}{2}$ is to $\frac{HI+IA}{2}$ that is, $\frac{3+3}{2}=3$ is to $\frac{3+2}{2}=2\frac{1}{2}$, this is in the proportion of 6 to 5, or the half weight at H is to the bottom weight at I, as 3 to 5.

Bisect A B by the perpendicular C D, and make the angle

AEC equal to half the vertical angle, or the angle EAC, equal to its complement. Make ED to EC as 5 to C; join DA and DB; in AD, take any point, F; draw FG parallel to AE, making AF to FG as 2 to 3; draw AGH, cutting CD at H, and HI parallel to FG or EA, cutting AD at I; make BK equal to AI, and join KH, then AIHKB is the contour of the roof required. This is so evident from its construction, that its does not require demonstration.

Proposition V. *Figure* 5.—To describe a roof with four equal rafters, that shall be in equilibrio by the weight of the rafters, of a given width AE, and height FC.

Join CE, and bisect it in H by a perpendicular, DHG, meeting AE in G; on G, as a centre, with the distance GE or GC, describe the circle CEO. Draw KHI parallel to FE, to meet the vertical line OC, in K, and the circle in I. Draw IDC, and join DE, than make the side CBA similar to CDE, and AB, BC, CD, DE, will be the rafters of the roof required.

For, in *Figure* 6, complete the parallelogram CDQB, and join BD, IF, and draw CL perpendicular to CF, and equal to FG; on L, with the distance GE describe the circle NIF, meeting the vertical line at N and F; produce ED to meet it also in M, and BC to P.

Then because KF is equal to KC, and RC equal RQ, the triangles GIF and CDQ, are similar; therefore IF is parallel to DQ, and because the two segments NIF and CEO are equal to one another, the angle NIF is equal to the angle GEO, equal to twice the angle CEF, or twice the alternate angle ECL, equal to ECD + DCL; but ECD is equal to half the external angle MDC, and DCL is half the angle DCP; equal to DCQ. Therefore the angle NIF is equal to the angles MDC + CDQ, equal to the angle MDQ, consequently, CF : CN : : CQ : CM, but CF and CN are equal, therefore CQ and CM are equal; but CQ is to CM as the weight on C is to the weight on B or D, therefore the weights on C and B are equal, and the rafters AB, BC, CD, DE, are in equilibrio.

CURB STONES, (sometimes written *Kerb* or *Kirb*,) those common to the foot and carriage pavements in a street.

CURIA, a court of justice. *See* BASILICA.

CURLING STUFF, that which is occasioned by the winding or coiling of the fibres round the boughs of the tree, where they begin to shoot out of the trunk.

The double-iron plane, now in use, is a most complete remedy against cross-grained and curling stuff; this plane, if well set, will work nearly as smooth against the grain as with it.

CURRENT, the necessary slope of a piece of ground or pavement, for discharging the water from the surface.

CURSOR, a point screwed on a beam-compass, and which may be moved or slid along the beam, for striking greater or less arcs of circles. It is also that part of a proportional compass which holds the two legs together, and by which the points are set in any given ratio. The sliding parts of the trammel, rood, or ellipsograph, are also called *cursors*. *See* COMPASSES.

CURTAIL STEP, the first step by which a stair is ascended, finishing at the end in the form of a scroll, following the plan of the hand-rail. *See* the article STAIR.

CURTAIN, (from the French *courtine*,) in fortification, that part of the rampart which is between the flanks of two bastions, bordered with a rampart five feet high, behind which the soldiers stand to fire on the covered way, and into the moat.

CURTICONE. *See* FRUSTUM and TRUNCATED CONE.

CURULE, a sort of raised, embellished chair or seat of ivory, gold, &c., placed in a chariot, wherein the chief officers of Rome were wont to be carried into council. It was also a mark of distinction for dictators, consuls, prætors, censors, and ediles, who were from this circumstance called *curules*. Curule chairs were of various shapes, but the one generally used was a stool without a back, so made as to be folded up, and opened again in the manner of a camp stool.

CURVATURE, that degree in a curve, in which the curve recedes in a perpendicular from a tangent, at a given distance from the point of contact; and consequently if two curves, or two parts of the same curve, have each a tangent, and if any equal distance from each point of contact be taken, and a perpendicular be drawn from each point of distance to the curve; then, in each of these curves, or portions of the same curve, the intercepted perpendicular being greater or less, the curvature will also be greater or less.

CURVE, a line, such that only one straight line can be made to touch, without cutting it, when the straight line is extended on both sides of the point of contact; or a curve is a line in which, if a point be taken, only one straight line can pass that point without cutting the line in which the point is taken. The straight line so drawn is called *a tangent* to the curve.

The circle is the most simple of all curves, depending only upon the arbitrary extension of its radius, which, if given, the circle is determined in magnitude. Its circumference is one uniform curve, or has its curvature everywhere equal, and equally distant from the centre.

In every curve line whatever, it is evident that a very small portion may be taken as a circular arc at any point; or that there is a certain circular arc at that point which has the same curvature as an indefinitely small portion of the curve, but a greater curvature than an indefinitely small portion of the curve upon the one side of the point, and also a less curvature than the nearest indefinitely small portion on the other side of the point. The radius of a circle of equal curvature to the curve at any proposed point, is called the *radius of curvature* at that point, and is the measure of the curvature of all curves. The circle of equal curvature with the curve, is called the *equicurve circle*, or the *osculating circle*. Hence, if the osculating circle and the curve have a common tangent, no other circle whatever can be drawn between the two curves; and when the curve is continually upon the increase or decrease in its curvature, the arc of the osculating circle will be on the concave side of the curve on one side of the point of contact, and on the convex side on the other side of the said point; or the curve will be between the tangent and the circumference of the osculating circle on the one side of the point of contact, but the circumference of the osculating circle will be between the tangent and the curve on the other side of the point of contact.

The principal curves that are useful in architecture, are the conic sections, namely, the circle, the ellipsis, the parabola, and the hyperbola; also, the cycloid, the conchoid, the spiral of Archimedes, and the logarithmic spiral. The definitions and the most useful properties, will be found under each word.

CURVE OF DOUBLE CURVATURE, a curve, of which all its parts are not in the same plane.

Thus, if the surfaces of two cylinders of the same diameter intersect each other, and their axes also intersect each other, the common intersection will be a curve, of which its parts are all in the same plane; or if the surface of a cylinder and cylindroid intersect each other, and their axes also intersect each other; and if the semidiameter of the cylindroid be perpendicular to a plane passing through the two axes, and equal to the radius of the cylinder, then the parts of the curve formed by the two surfaces, are likewise in one plane: or if the surface of one cylindroid meet that of another

cylindroid, and their axes intersect each other; and if the semi-diameters of both cylindroids, perpendicular to a plane passing through the two axes be equal to each other, the curve formed by the intersection of the cylindroidic surfaces will have all its parts in one plane: not any of these thus defined, are curves of double curvature. But if the surfaces of two cylinders of unequal diameters meet in a common line, this line is a line of double curvature: of this description are cylindro-cylindric groins. Many other instances of two geometrical solids meeting each other, producing lines of double curvature, may be laid before the reader, but perhaps what has already been adduced will be sufficient.

Curved Surface of a Solid, that in which, if any point be taken, and if the solid can be cut by a plane through the point, and thence form a section, such section is terminated by a curve: Thus a cylinder or a cone may be cut by a plane, through any given point, so as to make the common section of the cylinder or cone with the plane, a curve, or a straight line; but if a sphere, spheroid, or any of the conoids be cut by a plane through any point, the common section of the plane, and the surface of any such solid will be a curve.

CURVILINEAR, (from the Latin *curvus*, a curve, and *linea*, a line) or Curvilinear Figure, a superficies bounded by curve lines, or by a curve and straight line, when the properties of the curve depend upon the straight line.

The circle and ellipsis are entire curves, or such as have no straight line in their boundary; but the parabola and hyperbola are both bounded by a curve and a straight line.

Curvilinear Angle. *See* Angle.

Curvilinear Roof, that which is erected upon a curvilinear plan, as a circular, or elliptical, or portions of these curves.

Curvilinear Superficies of a Solid. *See* Curved Surface of a Solid.

Curvilinear Triangle, one whose sides are curves.

CUSHION RAFTER. *See* Principal Brace.

CUSP, (from the Latin *cuspis*,) one of the pendants of a pointed arch, or one of several pendants forming what may be denominated a polyfoil; two cusps form a trefoil, three a quatrefoil, four a cinquefoil, &c. In other words, the term may be explained as the points generated by the intersection of the small arcs or segments of circles, forming the foliations which frequently terminate the internal curves of Gothic arches, more especially window arches, in the shape of trefoils and other polyfoils.

This name was first given by Sir James Hall, of Dunglass, in an *Essay on the Origin of Gothic Architecture*. He says, in a note at the bottom of page 23, that "assemblages of these cusps are spoken of in the descriptions of Gothic works, by the means of trefoil, quatrefoil, semitrefoil, &c.; but no proper word has been used to describe the form, wherever it occurs, or however combined."

CUSTOM-HOUSE, an edifice in some chief city, or port, for the receipt of the customs and duties of importation and exportation imposed on merchandise, by the authority of the sovereign. The custom-house in Dublin is a very elegant edifice.

CUT, in inland navigation, the same with canal, branch, or arm.

Cut Brackets, such as are modelled on the edge.

Cut Roof, a truncated roof.

Cut Standards, for shelves, are those whose front edge is cut into mouldings.

Cut Stone, hewn stone, or that which is brought into shape by the mallet and chisel.

Cut-water, the lower portion of the pier of a bridge, where the two sides meet at a point, so disposed to meet the current, and offer as little resistance as possible to the force exerted by it against the pier.

CUTTING PLANE, a plane supposed to cut or divide a solid into two parts, in any position.

CUVILLER, FRANÇOIS, an architect, born in the year 1698, at Soissons, in France. He was employed by the elector of Munich in many public buildings, and continued in the service of that court till his death, which happened in the year 1760, leaving behind him many plans and designs, which were afterwards engraved by different artists, and published by his son, François Cuviller, who was born at Munich, and succeeded his father as architect to the court.

CYCLOGRAPH, (from the Greek, κυκλος, *a circle*, and γραφειν, *to describe*) in practical geometry, an instrument for describing the arc of a circle to any chord and versed sine; but chiefly used in flat segments, or those whose curvatures approach to straight lines. There are several constructions of cyclographs, of which the following is one. The principle consists of two rules, A B, and C D, connected by a folding joint, E, the pin, *k*, of which projects upwards, and is mortised to receive a bar, *h g*, which is fastened, but movable round the centre of the folding joints; upon the connected rules A B and C D, at equal distances, from the centre of the folding joint, are fastened the ends I and K, of two other equal bars *c* I, *c* K, connected by a movable joint, *c*, so as to form a rhombus, *h* K *c* I, movable round each of the joints, *c* I *h* K; then the bar, *h g*, which passes through the centre, *h*, of the two first rules, being made also to pass through a projection of the pin, *c*, of the opposite angle of the rhombus, is made to slide into the mortise as at *c*. The use of the bar is to fasten the instrument in any position by means of a screw inserted from the middle of the top of the upright pillar at *c*, which receives the sliding end of the bar.

The instrument being supposed to be placed upon a level plane, and the pin, *h*, of the folding joint being made to project upwards; another bar, L M N, bent to a right angle with a longitudinal slit, O P, is fitted upon it, so as to have a motion upon the pin *h*, in the section of the slit, but may be fastened at any required point, by means of a screw from the top. The other end, N, of this bar is mortised in the direction of the slit, to receive the lower bar, *h g*, so as to have a longitudinal motion. The middle line of the upper bar stands in the same vertical plane with the middle line of the lower bar, and these two lines are parallel in all positions of the instrument.

The end of the bar, L M, at the external side of the folding joint, has a deep socket for holding a pin or pencil, perpendicular to the plane of the instrument. The advantage of the upper bar being movable, to which the pin or pencil is attached, is to admit the point of the pin or pencil to be brought into the intersection of the sides B A, C D, of the instrument.

To describe the segment of a circle by means of the cyclograph, fasten two pins in the plane, or steel edges made on purpose, and adjust the angle of the instrument; place the outer edges upon the pins, and the angle close upon one of them; move the instrument laterally close to the pins, and a pen or pencil will describe the curve.

The principle of this instrument is founded upon the twenty-first proposition of the third Book of Euclid's Elements, in which it is announced and proved that "the angles in the same segment of a circle, are equal to one another."

This instrument may also be applied to the drawing of lines to any inaccessible points, by means of the middle bar, which always bisects the angle, and therefore will be indispensably useful in the practice of perspective.

CYCLOID, (from the Greek κυκλος, *a circle*, and ειδος, *form*) a figure described by rolling a circle upon a plane, along a straight edge; then the moving point will trace the curve called a *cycloid*, or *trochoid*. The middle portion of this figure is very appropriate for the arch of a bridge, which requires to have its roadway raised on the top, as the extrados of this curve has a gentle convexity.

CYCLOPEAN ARCHITECTURE, that practised by the early colonists of Greece, more remarkable for its massive construction than any other feature, whence also its name. *See* PELASGIAN ARCHITECTURE.

CYCLOSTYLAR, a term applied to those erections which consist of a circular range of columns, without a central building.

CYLINDER, (from the Greek κυλινδειν, *to roll*) a solid formed by moving a straight line in the periphery of a circle, parallel to another straight line, which passes through the centre, and which makes any given angle with the plane of the circle, until the line come again into its first position.

The surface described by the moving line from the circle to any indefinite extension, is called *a cylindric surface;* the straight line which passes through the centre of the circle is called the *axis* of the cylinder, and the circle the *base* of the cylinder.

If the axis be at right angles to the plane of the base, the cylinder is called *a right cylinder;* but if at oblique angles, then it is called *an oblique cylinder*.

Euclid confines his definition only to a right cylinder, and defines it to be a solid formed by revolving a rectangle round one of its sides.

It is evident from this definition, that all sections passing through the axis, or parallel to the axis, have their opposite sides parallel; viz., those which are formed by the cutting plane and the cylindric surface. From the definition here given, the following consequences may be drawn, as being too obvious to require any formal demonstration. If a plane, parallel to another plane, drawn along the axis of a cylinder, touch the periphery of the base, the plane so posited will touch the surface of the cylinder, and will meet it in a line parallel to the axis; but if such plane cut the plane of the base of the cylinder within its periphery, it will cut the cylindric surface in two parallel lines, and the common section of the plane and the cylinder will be a parallelogram, and, lastly, the common section of a plane, parallel to the base, with the cylindrical surface, is a circle with its centre in the axis. Let us now consider the property of a section which will meet the plane of the base of the cylinder, but which will neither pass along the axis, nor be parallel thereto.

Figure 1.—Let AMLB be a section of the cylinder through the axis, cutting the section proposed, and let the cutting plane meet the plane of the base AFEBNO in RS: through the centre D of the base, draw the diameter AB, at right angles to RS. Let the plane be drawn through AB and the axis DH of the cylinder, meeting the cutting plane in the line MHGLT, and the surface of the cylinder, in AM and BL. Through H and any other point, G, in ML draw QK and IP parallel to RS; through KQ and DH, draw the plane KQOF, and through IP draw the plane IPNE, parallel to the plane KQOF, cutting AB at C; and because KQ and IP are parallel to RS, the planes KQOF and IPNE, are also parallel to RS; therefore FO and EN, are respectively parallel to KQ and IP; consequently, the figures KQOF and IPNE, are parallelograms, and therefore KQ is equal to FO, and IP equal to EN: because EN is parallel to RS, it is at right angles to AB, and hence it is plain that IP is bisected by ML. Now the triangle AMT, has the side AT cut into several parts by the intermediate points D, C, B, and MT cut into other parts at the intermediate points H, G, L, by lines parallel to the side AM, and therefore the parts AD, DC, CB, are respectively in the same ratio with the parts MH, HG, GL; these being premised, we have therefore

$$AC : AD :: MG : MH$$
$$CB : AD :: GL : MH$$

Therefore $AC \times CB : AD^2 :: MG \times GL : MH^2$

but $AC \times CB = EC^2 = GI^2 \;\&\; AD^2 = HK^2$

consequently $GI^2 : HK^2 :: MG \times GL : MH^2$

therefore the section is an ellipsis.

But this demonstration, which is in principle that commonly given, only shows the general property in respect of the axis, or at most in respect of only two conjugate diameters, of which one must be parallel to the base; and as we have never seen a general proof of this valuable property for any two conjugate diameters drawn from simple principles, without being under the disagreeable necessity of drudging through nearly a whole treatise of conic sections, before we are able to arrive at the conclusion, we therefore subjoin the following demonstration.

Figure 2.—Let there be any cylinder, right or oblique, standing upon the base GEAPQD, and let C be the centre of the base; through C draw GQ at pleasure, and ACD at right angles to GQ. Through GQ and the axis CM draw the plane GQSH, cutting the section proposed in the straight line HS, also through AD and the said axis draw the plane ADNK, cutting the section in the straight line KN. In one of the diameters, AD, of the base, take any point, B, between A and C, and draw EP parallel to GQ, and the plane EPRF, parallel to the plane GQSH, cutting the section in FR.

From the construction of the cylinder, it is evident that the lines KN, FR, HS, are each divided into parts, which are as the parts of the lines AD, EP, GQ. Therefore as EP, GQ, and AD, are bisected, so will FR at L, HS at M, and KN at M.

From the premises we have . . . . $AB : AC :: KL : KM$

and by proportional lines . . . . $BD : AC :: LN : KM$

Now, by multiplying the homologous terms . . . . $AB \times BD : AC^2 :: KL \times LN : KM^2$

But from the property of the circle . . . . $AB \times BD = EB^2 \;\&\; AC^2 = GC^2$

Therefore, by substitution, we have . . . . $EB^2 : GC^2 :: KL \times LN : KM^2$

Now again, by proportional lines . . . . $EB : GC :: FL : HM$

Squaring the terms of the last analogy . . . . . . $EB^2 : GC^2 :: FL^2 : HM^2$

but by the fourth analogy, we have . . . . $EB^2 : GC^2 :: KL \times LN : KM^2$

And by comparing the antecedents and consequents of the last two analogies we obtain . . . . $FL^2 : HM^2 :: KL \times LN : KM^2$

which is a general property of every two diameters, formed by the intersection of planes passing along the axis at right angles to each other. These diameters, it is evident, will be parallel to tangents to the curve, at the extremities of each other. For, suppose two planes touching the cylindric surface, each in a line which passes from the extremities of each radius at a right angle with each other, these tangent planes will be respectively parallel to each plane passing along the axis and through the said radii; the two tangent planes, and the two planes passing along the axis, will be at right angles to each other, or each opposite pair will be parallel; therefore, if these be cut by a fifth plane, the intersections of the opposite planes with such fifth plane, in any position, will be parallel lines; and since the touching planes do not cut the surface of the cylinder, the lines at the extremities of each diameter will be parallel to the curve, and are what are termed *conjugate diameters.*

A cylinder is a species of prism, because all its parallel sections are equal, and every section parallel to the base is equal to that base; therefore the solidity of a cylinder is determined by multiplying the area of an end by the parallel distance between the two ends.

Example I. What is the solidity of a cylinder, whose height is 10 feet, and the diameter of the base 2 feet 6 inches?

in.
$6 = \frac{5}{10} = .5$ in decimals
$2.5 =$ the diameter
2.5
———
125
50
———
6.25
.7854
———
2500
3125
5000
4375
———
4.908750
10
———
49.087500

Example II. What is the solidity of a cylinder, the circumference of the base being 7.85 feet, and the height 15 feet?

7.85
7.85
———
3925
6280
5495
———
61.6225
.07958
———
4929800
3081125
5546025
4313575
———
4.903918550
15
———
24519592750
4903918550
———
73.558778250

The curved surface of every cylinder is equal to a rectangle, one of whose dimensions is the length of the axis, that is, equal to the length of the side of the cylinder, and the other dimension equal to the perimeter or girt. This is a general principle, whether the cylinder have its ends perpendicular or oblique to the axis; and hence the following—

Rule. Multiply the girt of the cylinder by the length of the axis, and the product will be the cylindric surface.

Example. Suppose a cylinder, girt 5 feet 9 inches, and the length of its axis, or side parallel to the axis, be 9 feet 7 inches, what is the superficial content of the surface?

Cross Multiplication.	Decimals.
ft. in.	
5 9	9.583
9 7	5.75
5 3	47915
35	67081
81	47915
12) 121	55.10225
	12
10 1	
45	1.22700
	12
55 . 1 . 3	2.724

See the first method in this example under the article Cross Multiplication, and the second method, under Decimal Multiplication. These two methods would have agreed exactly, but no decimal corresponding to 7 inches can be precisely found.

The method by the girt is what every man in practice would naturally prefer, if the object be before him, since the girt can be as easily measured as the diameter, and with equal accuracy, by means of a string; nor would any person, whose mind is crowded with the affairs of business, take the additional trouble of finding the circumference from the diameter, when it may be so expeditiously obtained another way. However, for the satisfaction of those who wish to be informed of every mode of operation, we shall add the following, as some cases may occur, in which the perimeter cannot be obtained without the diameter; though the contrary might as likely be the case.

If the cylinder be a right cylinder, find its circumference, which will then be the same as its ends; then proceed as before to multiply the circumference by the axis, and the product is the superficial content. This is so easy as not to require an example. But where the axis is inclined to the base, the section of the cylinder will be elliptic, the diameter of the circular ends will be the greater axis, the lesser one will depend upon the inclination of the cylinder, and may be thus found :—

As the radius
is to the sine of inclination,
so is the diameter of the circular ends
to the shorter axis of the ellipsis.

From the two axes being now found, find the perimeter of the ellipsis, then proceed as in the first rule.

Example. Suppose the length of the axis to be 22 feet, and the inclination of the same to the plane of the base 50 degrees, and the diameter of each end 3 feet 6 inches; required the area of the curved surface.

By logarithms.

Then as radius	10.000000
is to the sine of 50°	9.884254
so is 3.5	544868
	10.428322
	10.
to the shorter axis	.428322 = nat. num 2.68

2.68
3.5

2) 6.18

3.09 mean diameter.

$3\frac{1}{7}$

9.27
.44

9.71 elliptic primeter.
22

1942
1942

213.62 the area required.

The above method of finding the extension of the elliptic primeter being the most expeditious, is the most useful for practical purposes, but those who wish to work with greater accuracy may consult the word *Ellipsis*.

A cylinder is said to be given in position, when its base and magnitude, and the inclination and length of its axis, are given.

A point is said to be given on the surface of a cylinder, when its distance from that point to the base, measured in a line parallel to the axis is known, and the point on the circumference of the base given.

Figure 3.—*Given a right cylinder and three points on its surface to find the section of the cylinder, by a plane passing through the three points.* Let the straight lines, A, B, C, be the distances of the three points, the circle D E F K, the base of the cylinder; L the centre of the base. Through the points D and F draw the straight line P O; perpendicular thereto draw each of the lines D G, E H, F I, respectively equal to A, B, C. Draw D E Q and G H Q, intersecting at Q; also draw G I O, meeting P O in O, then Q O, which is the intersection of the cutting plane. Through L draw R L S T, cutting Q O at T. In G O take any point *m*, draw *m u* perpendicular to G O, produce *u m* to M in O P, and draw M U perpendicular to P O, cutting Q O at U. From the point O, with the distance O U, describe an arc, cutting *m u* at *u;* perpendicular from R T, draw R P and L N, cutting P O at P and N. Draw P *p* and N *n* perpendicular to P O, cutting O G produced at *p*, and *n*. Parallel to *u* O, draw the lines *p r* and *f n l h;* make O *t* equal to O T and *p r* equal to P R, and draw *r l s t;* make *l s* equal to *l r*, and *l g* and *l h* each equal to R L, the semi-diameter of the base, then will *l r l f* be the semi-axis of the elliptic section.

Demonstration.—It is shown under the article INCLINED PLANES, that if D, E, F, be any three points, and the lines A, B, C, the height of three points in the space above the plane D E F, that Q O will be the intersection of the plane in space with the original plane P O Q or its continuation: under the article STEREOGRAPHY and STEREOTOMY it is shown, that if P O Q and P O *p* be any two plane angles, to be placed at a right angle with each other, that the plane angle G O *u*, will be the hypothenusal plane, and consequently when the three planes, P O Q, P O *p*, and *p* O *u* are turned into their position; the straight line O *u* will coincide with O U; therefore, if a plane be perpendicular to the intersection of two planes, it will be at right angles to each of these planes; and that the section of any vertical line, whose seat is given, will be found by drawing a line on the original plane, parallel to the intersection from the seat, to the intersecting line of the vertical plane; thence a line perpendicular to this intersection to the common intersection of the vertical and cutting planes, and thence a line from this point parallel to the cointersection; then, by making this line equal to the line drawn from the seat to the common intersection of the original and inclined planes, and thus the point R being the seat of *r*, and *l*, the seat of L, and the plane passing through R L S T, being perpendicular to Q O, the common intersection of the inclined and original planes, *r l s t* will be the intersection of a plane passing through the axis and at right angles to the intersection O Q, and therefore perpendicular to O *u*; consequently *r s* and *f h* are at right angles to, and bisect each other, and are therefore the axes of the ellipsis.

The segment of a cylinder is any portion of the cylinder made by a plane parallel to the axis.

The plane parallel to the axis is called the *chord-plane*.

The two lines of concourse formed by the cylindric surface and the chord-plane, are termed the *sides* of the chord-plane, and the other two lines of concourse made by the chord-plane and the two ends of the solid, are termed the *bases or ends* of the chord-plane.

A line of position is said to be given, when the said line is drawn through a given point on each side of the chord-plane, or to make a given angle at a given point in the base of the chord-plane, or in the base continued.

The position of the cutting plane is said to be given, when the line of position through which the cutting plane passes, and the angle which the cutting plane and chord plane make with each other, are known.

Figures 4 and 5.—*To find the section of the segment of a cylinder; given its base and the position of the cutting plane.*—Let A B C be the base of the solid, A D and C E the sides of the chord plane perpendicularly situated in respect of A C, the chord of the base, and let D E be the line of position of the cutting plane. Through any point *f* in D E draw *h f g*, at right angles to D E; make the angle *g f k* equal to the inclination which the planes of the chord plane and section make with each other; take any point *m* in *f g*, *Figure* 4, or *f h*, *Figure* 5, and draw *m k* parallel to D E, cutting *f k* in *k*, and *m n* parallel to C A, cutting D E at *n;* make *f h* equal to *f k*, and join *h n*. Parallel to E C draw *m q*, cutting A C at *p*, and *n r*, meeting it at *r:* make *p q* equal to *m k*, and join *r q*. To find any point in the curve of the section, take any point, *a*, in the arc A B C; draw *a b* parallel to *q r*, cutting A C at *b;* draw *b c* parallel to C E, cutting D E at *c*, and draw *c d* parallel to *n h;* make *c d* equal to *b a*, and the point *d* is in the curve.

In the same manner, as many points may be found as will be sufficient to draw the curve with accuracy.

This method is an improvement upon that published in *The Carpenter's Guide*, in the year 1792; but as that method has been very generally employed, it will be well to insert it likewise in the plate, as the connection of the principle may be clearly deduced from the one to the other.

Figures 6 and 7.—*To find the section of the segment of a cylinder, by another and older method, supposing everything given as before.*—Let A B C, No. 2, be the inclinations of the

planes of the chord plane and section. In No. 2, draw B D perpendicular to B A, and make B D equal to the distance between the parallel lines E F and Z M, No. 1, and draw D C parallel to B A. Through any point, *d* in I K, No. 1, draw N V at right angles to I K; make *d* N equal to D C, No. 2, and *d* V, No. 1, equal to B D, No. 2. In No. 1 draw N O parallel to F E, meeting I K at O, and join O V. Draw N Q and O L parallel to K F, meeting E F at Q and L; produce N Q, meeting Z M produced at Y, and join L Y. Draw any number of lines *a a*, *b b*, *c c*, &c., parallel to O L, cutting the lines E F and I K, at the points *a*, *b*, *c*; from the points *a*, *b*, *c*, in I K, draw the lines *a* 1, *b* 2, *c* 3, &c., parallel to O V, and through the points *a*, *b*, *c*, in E F, draw the lines *a* 1, *b* 2, *c* 3, &c., parallel to L Y. Make all the lines *a* 1, *b* 2, *c* 3, &c., from I K, equal to their corresponding distances *a* 1, *b* 2, *c* 3, &c., from E F. A curve being drawn through the points 1, 2, 3, &c., the extremities of the ordinates from I K, will give the section I V K I of the segment of the cylinder. Or take any point point L in E F, and draw L O parallel to F K, the one side of the rectangle, cutting I K at O; produce O L to M, and draw Z M parallel to E F, to touch the base in M. In No. 2, draw B D at a right angle with B A; make B D equal to L M, and draw D C parallel to B A. In No. 1, draw G H parallel to I K, at the distance D C, No. 2; draw O N parallel to E F, cutting G H at N; draw N Q parallel to O L, cutting E F at Q; produce N Q to meet Z M produced at Y, and join L Y; draw N V at right angles to I K, cutting I K at *d*; make *d* V equal to B C, and join O V; then proceed to find the ordinates as before.

The difference between the old and the first method is, that in the old method, the breadth of the segment or base of the solid is limited, in order to find the dissecting lines of the ordinates, and two diagrams are employed in the construction; whereas in the first method, one diagram only is used, and the angle of inclination of the planes of the section and chord being made as directed, the measure of the first side of the hypothenusal side of the right-angled triangle formed by it, is arbitrary; by this the other parts are regulated. The reader must observe, that it is only the angles which are required; the length of the lines is of no other consequence than, if they be too long, they will be rather cumbrous, and if too short they will not be a sufficient guide for drawing the ordinates. This limitation has been the occasion of some not understanding the principle, by supposing the point V to be in the curve, which may be either on the one side or the other, according to this method.

A knowledge of the sections of prisms, which include segmental cylinders, is an acquisition of the first importance to the carpenter and joiner, and is the very essence of the art of constructing hand-railings and groins.

The method by having the position of the cutting plane, is not so well adapted to practice, as that of having three given points on the surface of the segmental cylinder.

Under such given data we have already shown how the section is to be found for a whole cylinder, by describing the curve through the extremities of the axis, which are given in position. We shall now show how the curve is to be obtained by ordinates in the segmental cylinder from the same data.

In a segment of a cylinder are given three points, one on each common line of the chord-plane, and curved surface, and one upon the intermediate curved surface itself, to find the section passing through these three points.

Figures 8 and 9.—In both figures let A B C be the base of the solid, and A, B, C, the seats of the given points, draw A D and C E perpendicular to A C: make A D equal to the height of the point upon its seat A, and C E equal to the height of the point upon its seat C; also from C E take C F equal to the height of the intermediate point, from its seat B. Draw F G parallel to A C, cutting D E in G; draw G H parallel to E C, cutting A C at H; join H B. Produce C A and E D to meet in I; in E I, *Figure* 8, also in E I produced *Figure* 9, take any point, N, and draw N M perpendicular to N E; produce M N to meet I C at K, *Figure* 8; in *Figure* 9, M N will cut C I, produced in K. In both figures draw K L perpendicular to K C, and I L parallel to H B; from I, with the distance I L, describe an arc, cutting N M, at M; join I M.

To find any point in the curve of the section; take any point *a*, in A C, and draw *a b* parallel to L I, cutting the arc A B C at *b*, draw *a c* parallel to C E cutting D E in *c*; draw *c d* parallel to I M; make *c d* equal to *a b*, and *d* is a point in the curve. In the same manner as many points may be found as will be sufficient to complete the section.

Another method *Figure* 10, let A B C be the base of the segment as before; also, let A, B, C, be the seats of the three points, as before; and F G H their respective heights. Draw A D, B P, C E, each perpendicular to A C, respectively equal to F, G, H; draw A B I and D P I, also A C K and D E K; then draw the intersection I K. In D K take any point L, and draw L M perpendicular to D K; produce M L to meet A K at N; draw N O perpendicular to A K, cutting I K at O. From K, with the distance K O describe an arc, cutting L M at M, and join K M.

Then, to find any point *d*, in the curve of the section; in A C take any point *a*; draw *a b* parallel to K O, meeting the arc A B C at *b*; draw *a c* parallel to A D, meeting D E at *c*; draw *c d* parallel to K M, and make *c d* equal to *a b*; and thus for any other point.

The very same description of words applies to *Figure* 11, except that the point L is in D K produced, instead of between D and K, and also the point N, in A K produced, instead of between A and K. The same is also the case with the preceding method.

Figure 12. To form the edge of the envelope of a cylindric surface, terminated by a line, so that, when the envelope is folded upon the cylindric surface, the edge formed may coincide with a plane passing through three given points, one in each common line of the chord-plane and curved surface, and the other in the intermediate curved surface itself.

Let A B C be the base of the solid; draw A D and C E perpendicular to A C, making A D equal to the height of the point, whose seat is A, and C E equal to the height of the point, whose seat is C; make C F on C E equal to the height of the point, whose seat is B, and join D E. Draw F G parallel to C A, cutting E D at G; draw G H parallel to E C, cutting C A at H, and join H B. Divide the arc A B C into any number of equal parts, and extend them upon A C produced to I, marking the points of division at *a*, *b*, *c*, &c., to I; the corresponding points of 1, 2, 3, &c., on the arc C A B.

To find any point in the line of the envelope required, suppose that which corresponds to its seat 1, on the base of the solid.

Draw 1 *h* parallel to B H, cutting A C in *h*; draw *h h* parallel to C E, cutting E D at *h*; also draw *a p* parallel to C E, and make *a p* equal *h h*, then *p* is a point in the line required; and thus the whole line E *p q r s t u v* K is obtained, and this line is the edge of the envelope E C I K required.

CYLINDER, *Scaline.* When the axis of a cylinder stands at oblique angles with its base, it is called *a scaline* or *oblique* cylinder.

CYLINDRICAL, something peculiar, similar, or relating to a cylinder.

CYLINDRICAL CEILING, a ceiling which is either a semi-cylinder, or a segment less than a semi-cylinder.

Cylindrical ceilings are vulgarly called by some workmen *waggon-headed ceilings.*

When an apartment is sufficiently high, a semi-cylindric

coving ought to be adopted, as it rises from the surface of the wall, which forms a tangent plane to the curvature at the springing of the arch; whereas the tangent plane at the springing of a ceiling, which is less than a semi-cylinder, always forms an angle with the plane of the wall, and excites the idea of lameness or imperfection. This kind is therefore only employed when the height of the apartment is not sufficiently great to admit of a semi-cylindric ceiling.

A semi-cylindrical ceiling admits of being pierced by lunettes, which are windows or openings of less height than the ceiling, and consequently form cylindro-cylindric arches, by the intersection of the curved surfaces.

No traces of cylindrical ceilings are to be found among the ruins of Grecian edifices, but numerous instances are to be met with among the Romans, in their small temples and the side-branches of the larger ones. The ceiling of the temple of Æsculapius, in the palace of Dioclesian, at Spalatro, in Dalmatia, is a decided instance. The proper decorations for cylindrical ceilings are coffers, separated at regular intervals by bands or *arcs doubleux*, or, as called by some, *soffits*, which are enriched with guilloches.

Cylindrical Column. *See* Column.

Cylindrical Vaulting, a vault which is the portion of a cylinder. Its section is generally a semicircle, though sometimes, for want of room, it is a smaller segment. In cylindrical vaulting, the equilibrium of the arch and the horizontal thrust of the piers must be attended to.

Cylindrical Walling, is that erected upon a circular plan, which of course forms a cylinder, or a portion of a cylinder, according as the plan is an entire circumference, or only a segment.

Cylindrical walling is generally estimated at about half as much more than the price of plain walling; but the price or ratio ought to depend upon the diameter, and should be greater as the diameter is less.

Cylindrical Work, any kind of work, partaking of the shape of a cylinder, of any material, whether stone, brick, wood, &c.

Cylindrical Work, in joinery. *See* Joinery.

CYLINDROID, (from κυλινδρος, *cylinder*, and ειδος, *form*) a solid of such property, that all sections parallel to either end, are equal and similar ellipses, and that a straight line, called the *axis*, will pass through the centre of the ellipses.

All the axal sections of a cylindroid, and every section parallel to an axal section, are parallelograms or rectangles.

All parallel sections of a cylindroid are equi-angular, and of equal length to the axis.

If an oblique cylinder be cut by a plane perpendicular to the axis, near to each end, it will be cut into three parts, of which the middle portion will be a cylindroid.

The cylindroid is frequently employed in vaulting, instead of a segmental cylinder, less than the half, where the height would not admit of a semi cylinder. It is frequently employed in the composition of groins, and where the transverse openings vary in their horizontal dimensions, and where it is required to keep the angles of the groin straight, one of the simple vaults is necessarily a semi-cylindroid.

The solidity of a cylindroid is found, as in the prism or cylinder, by multiplying the area of one of the ends by the distance between the two.

The superficial content of the curved surface is found by multiplying the girt by the length of the axis, as in the cylinder.

The method of finding the envelope is the same as that of a cylinder with an edge, so that when the envelope is lapped round the solid, its edge may coincide with a plane passing through three given points.

The method of finding the envelopes of cylinders and cylindroids, is one of the most useful parts of Stereography, not only in forming the coverings of bodies, but in forming the angles of all parts of work, where the surfaces of two different solids meet each other.

CYMA-RECTA. *See* Cymatium.

CYMATIUM, Cima, Cyma, or Sima (from κυματιον, *undula*, the diminutive of κυμα, *a wave*) a moulding, whose section is a curve of contrary flexure; it is commonly denominated by workmen *an ogee*. This is the strict sense in which the term ought to be employed, though Vitruvius uses it for any subordinate moulding which terminates a principal member, and the particular form is specified by prefixing another word, as Doric cymatium, Lesbian cymatium. In the same sense also he uses the word *Cysis*, which signifies *separation*. But notwithstanding this great authority, in the general usage of the term we shall abide by the definition as above, signifying an *undulated form*, as being most generally understood.

When the concave part of the moulding projects beyond the convex part, the cymatium is denominated a *sima-recta*; but when the convex part has the greatest projection, the cymatium is denominated a *sima-inversa*. The sima-recta is otherwise called *gula-recta*, or *doucine*, and the sima-inversa, *gula-inversa*, or *talon*. Palladio distinguishes the cymatium of the cornice by the name *intavolata*. Our architects, in speaking of the uppermost member of a cornice, call it *cima*, *cyma*, or *cymatium*; but we see no reason for the word being appropriated to this situation, as the propriety of terms consists in their proper application to definite forms.

The cymatia which are particularized by the terms *Tuscan*, *Doric*, and *Lesbian*, mentioned by Vitruvius, are not defined by this ancient author, and their meaning is only guessed at by his commentators and readers.

The Tuscan is supposed to be an ovolo, or quarter-round; the Doric, an ovolo, or cavetto; and the Lesbian, the sima-inversa, or talon.

Philander makes two Doric cymatia, one of which, he says, is that said to be Tuscan. The projecture allowed to the Doric and Lesbian cymatia, is subduple of the height.

CYMBIA, a fillet. *See* Fillet.

CYPHERING. *See* Chamfering, which is most in use.

CYZICENE, Triclinium, or Hall, an apartment of ancient Grecian houses, in the porticos, which look towards the north.

It is thus explained by Vitruvius, book vi. chap. vi. "There are some *œci*, not made in the Italian manner, these the Greeks call *cyzicenus*. They are situated towards the north, generally have a view of the garden, and have valved windows in the middle. They are of such length and breadth, that two triclinia, with their surrounding appendages may be placed opposite to each other; they have also valved windows on the right and left, that the garden may be seen through the space of the windows: their height is equal to one and one-half their breadth."

The cyzicenus or cyzicena, were of the same use among the Greeks, that the triclinia and cœnacula were among the Romans.

CYZICUM MARMOR, a species of marble, so called by the ancients, from the great use made of it by a statuary named *Cyzicus*. It was white, with fine narrow veins of black, and was also called *proconnessium*.

D.

DADO (an Italian word, signifying a *die*), a term for the die or plain face of a pedestal; that part of a room comprehended between the base and surbase. The dado employed in the interiors of buildings, is a continuous pedestal, with a plinth and base moulding, and a cornice or dado moulding surmounting the die. This continuous pedestal with its moulding is sometimes only made of stucco or plaster; but in well-finished rooms is constructed of wood, and is usually about the height of the back of a chair. Its present purpose, when employed, is to protect the stucco-work or paper of the walls, but originally it was used as an architectural decoration to a room.

The dado is made of deal boards, glued edge to edge, the heading joints ploughed and tongued together, and the back keyed; the stuff generally employed for this purpose is whole deal; the keys are always made to taper in their breadth, and may be about three inches broad in the middle; they are let into the back of the dado by a transverse groove, which is either wider at the bottom than at the surface, or it is first made of a square section, which is again grooved on each side next to the bottom. Though the keys should shrink, those of this last form will always keep their inner surface close to the bottom of the grooves.

Some workmen prefer the broad end of the key to be placed downwards; the lower end should rest firmly, either upon the ground or floor, and the dado should be left at liberty to slide downwards upon the keys. Others, again, prefer the wide end of the key to be placed upwards, and the dado to be fixed by this; the key, as it shrinks, will fall down from its own weight.

The dado should be grooved and tongued at the internal angles, and mitred, or made with a lap and mitre, at the external ones.

The dado is also framed with panels, but this mode is seldom seen in London; it is, however, very frequently so prepared in the country.

DAGOUNG, or Shœdagon, *temple of* (signifying temple of Golden Dagon) an edifice situated about two miles and a half north of Rangoon, the chief port of the Birman empire. It is a very elegant building, and though not so high by 25 or 30 feet, is much more ornamental than that of Shœmadoe, at Pegue.

It is surrounded by a terrace, which stands upon a rocky eminence, considerably higher than the circumjacent country. The building is ascended by 100 steps, which are now very much in decay; its elevated situation makes it a conspicuous object for many miles. The top and the whole spire are richly gilt, so that when the sun shines, they exhibit a most splendid appearance.

DAIRY, the name usually given to the place where the milk of cows is kept, and converted into butter or cheese. The occupation is sometimes called *dairying;* and the land which is chiefly appropriated to feed cows for this purpose, is called a *dairy-farm.*

"A dairy-house," observes a writer in the Penny Cyclopædia, "should be situated on a dry spot somewhat elevated, on the side of a gentle declivity, and on a porous soil. It should be on the west or north-west side of a hill, if possible, or at least sheltered from the north, east, and south, by high trees. In some countries, where there are natural caverns with an opening to the west, and springs of water at hand, the best and coolest dairies are thus prepared by nature. Artificial excavations in the sides of freestone rocks are sometimes formed for the purpose of keeping milk, and more frequently wine. Where no such natural advantages exist, the requisite coolness in summer, and equal temperature in winter, which are essential in a good dairy, may be obtained by sinking the floor of the dairy some feet under ground, and forming an arched roof of stone or brick. In cold climates flues around the dairy are a great advantage in winter; and an ice-house in warm summers is equally useful. But these are only adapted to those dairies which are kept more as a luxury than as an object of profit. In mountainous countries, such as Switzerland, where the summers are hot in the valleys, and the tops of the mountains or high valleys between them are covered with fine pastures, the whole establishment of the dairy is removed to a higher and cooler atmosphere, where the best butter and cheese are made. Coolness is also produced by the evaporation of water, an abundant supply of which is essential to every dairy. It is also a great advantage, if a pure stream can be made to pass through the dairy, with a current of air to carry off the effluvia, and keep the air continually renewed."

The dairy, in farm building, should be so situated, with respect to other offices, as to be convenient, and to prevent unnecessary labour.

A milk dairy requires at least two good rooms, one for the reception of the milk, and another for the purpose of serving it out, and for scalding, cleaning, and airing the different utensils.

The entrance to the dairy should communicate with the scalding-room, which should have a copper, for heating water and other purposes, placed in a shed adjoining, in order that the heat may be kept at as great a distance as possible from the milk. In the bottom of the copper is fixed a cock, for conveying the hot water through a trough or pipe, across the scalding-room, in which another cock should be fixed, for the convenience of washing smaller utensils; the heated water passes through the wall into the milk-leads for the purpose of scalding the whole range of pans, trays, or coolers, and may be retained at pleasure. The trough for the passage of the water through the walls of the dairy, should be of sufficient dimensions to admit the discharging a pailful of milk into it with safety, having a hair-sieve so placed in it, that the whole of the milk of the cows may be made to pass through it into the necessary trays or coolers, in which it is to stand in order to keep it clean. A trough, pipe, or some other contrivance, should be introduced, for the purpose of conveying the waste milk, whey, &c., from the dairy-house to the cisterns containing the wash for the pigs.

The temperature may be regulated either by double walls and roofs, or by means of hollow walls; and for common purposes, by having 8 or 10 inches in width from the wall to the lath and plaster, as is suggested by Mr. Loudon, in his *Treatise on Country Residences.*

The size of milk-houses should be regulated by the number of cows. The usual dimensions in the Gloucester dairy-houses, for 40 cows, are 20 feet by 16, and for 100 cows, 30 feet by 40. To accomplish the objects of convenience, the situation of the dairy should be near the cow-standings, so that the milk may be readily conveyed to them. See

Dr. Young's *Calendar of Husbandry*, and Mr. Loudon's *Treatise on Country Residences.*

Gentlemen's dairies are often built expensively, and highly ornamented; but they seldom unite all the conveniences essential to a good dairy, generally from a want of practical knowledge of the subject in those by whom they are designed. In Switzerland and Holland, the cow-house and dairy often have a very neat appearance within a short distance from the principal residence. In the common dairy-farms in Holland, the farmer and his family frequently live under the same roof with the cows; in north Holland and Friesland, a cow-house is as clean as any dwelling-house, and the family often assemble and take their meals in it.

The following description of a cow-house and dairy under one roof, combines all that is useful, with considerable neatness internally and externally. "It is a building about sixty feet long, by thirty wide, with a veranda running round three sides of it. The dwelling is not here attached, as it usually is in common dairies, and the building is not surrounded by a farm-yard; these are the only circumstances in which it differs from that of a common peasant. The dairy-room is sunk below the level of the soil, and is paved with brick. The sides are covered with Dutch tiles, and the arched roof with hard cement. The cow-house, like all in Holland, has a broad passage in the middle, and the cows stand with their heads towards this passage, which is paved with clinkers or bricks set on edge. Their tails are towards the wall, along which runs a broad gutter sunk six or eight inches below the level of the place on which the cows stand. This gutter slopes towards a sink covered with an iron grate, which communicates by a broad arched drain with a vaulted tank into which all the liquid flows. The gutter is washed clean twice a day before the cows are milked. The cows stand or lie on a sloping brick-floor, and have but a small quantity of litter allowed them, which is removed every day, and carried to the dung-heap, or to the pig-sties, to be more fully converted into dung. Whenever the litter is removed, the bricks are swept clean, and in summer they are washed with water."

In Holland, the cows never leave the house from November till May. In summer they are driven home to be milked, if in pastures near to the cow-house, but if the pastures are far off, they are milked there, and the milk is brought home in boats. This is thought not so good for the butter, which is then churned from the whole quantity of the milk, without allowing the cream to rise. The finest butter is always made from the cream as fresh as possible, and the milk should, to make this cream rise, be set as soon as milked. The best quality of butter is churned from cream skimmed from the milk after six hours setting; an inferior kind, from a second skimming.

The utensils of the dairy, such as pails, churns, vats, &c. are usually made of white wood, and require to be kept, as does everything about a dairy, scrupulously clean and neat. Utensils of brass and tin are sometimes used; in Holland, the milk is invariably carried in brass vessels. There is some danger in the use of brass utensils, but a very little attention will obviate it. Cast-iron pans have been invented, tinned inside; but there is nothing so safe, or so neat, as well-glazed white crockery ware of the common oval from.

A dairy for cheese, well constructed, should consist of four rooms: one for the reception of the milk; another for the scalding and pressing of the cheese; a third for the purpose of salting; and the fourth for stowing the cheese, which last may be a loft made over the dairy, though it is sometimes placed at a distance, which makes it inconvenient.

The butter dairy should consist of three apartments, namely, a milk-room, a churning-room, and a room for the different utensils, and for cleaning and airing them in. The churning-room should be fitted up with the necessary apparatus.

DAIS, or Deis, the raised platform or wooden flooring which was laid at the upper end of a large hall or banqueting room, such as is still seen in college-halls, and in most of the halls belonging to the city-companies in London, and those of the inns of court.

In royal halls, there were more than one *deis.* At a dinner which Charles V. of France gave to the emperor Charles IV. in 1377, there were *five deis.* The principal table in entertainments of state is always placed on the dais.

Also a seat with a high back, and sometimes with a canopy, for those who sat at the upper table. Sometimes the canopy itself.

DAM, a boundary or confinement; as, to dam up, or, to dam out.

Dam, a bank, or mole, constructed of stone, timber, or any other materials, for penning up water, in order to divert its course into another direction, for turning a mill, or other purpose. *See* Embankment.

DAMPER, a valve inserted in a flue to regulate the draught.

DANCETTE, a name applied to a moulding very frequently employed in Norman architecture, and otherwise termed the *chevron* or *zigzag moulding.*

DARK TENT, a portable camera obscura, formed like a desk, and fitted up with optic glasses, to take prospects of buildings and fortifications.

DATUM-LINE, the base line of a section from which all the heights and depths are calculated.

DAY, or Bay, one of the lights or compartments in great windows of the pointed style of architecture, from mullion to mullion, clear of any intermediate one.

In the Saxon and early Norman styles, windows of moderate dimensions were without mullions; but upon the introduction of the pointed arch, windows becoming long and narrow, two of these lancets placed together, in order to transmit a sufficient quantity of light, suggested the idea of a single mullioned window, which therefore contained two days or bays. From this junction, windows with two or more mullions, and three or more days or bays, succeeded, until the number of days or bays were multiplied to seven, or even nine. The windows thus comparted, were decorated with an endless variety of tracery, consisting principally of trefoils, quatrefoils, Catharine-wheels, &c.

From the time of king Henry VIII., mullioned windows were superseded again by plain windows. And thus the rise and fall of the great eastern and western windows in our cathedrals.

DEAD SHOAR. *See* Shoaring.

DEAFENING, a term used in Scotland for sound boarding; sometimes also used in wooden partitions for the same purpose, viz. for preventing the communication of sound.

Deafening, in plastering, a term used in Scotland, for Pugging, which see.

DEAL (from the Dutch, *deel*) the wood of the fir-tree, as cut up for the use of building, which is of two kinds, yellow and white.

Deals are chiefly imported from Christiana, and other parts of Norway; from Dantzig, and several parts of Prussia; from Petersburg, Archangel, and various parts of Russia. They are sold by the piece or standard.

In London, stuff that is kept on hand, consists generally of deals of various lengths, most commonly three inches thick, and seldom exceeding nine inches wide. They are broken or cut down into various thicknesses, called *boards* or *leaves,* so that a deal will always have one cut less than there are leaves.

When the leaves are thinner than half an inch, the deal will divide into five or more parts, and is therefore termed *five-cut stuff*, and thus the qualifying word is applied according to the number of pieces. Whole deal is one inch and a quarter thick, and slit deal the half of that.

Deals are formed by sawing the trunk of a tree into longitudinal pieces, of more or less thickness, according to the purpose they are intended to serve. They are rendered much harder by throwing them into salt-water as soon as they are sawn, keeping them in three or four days, and afterwards drying them by exposing them to the air: but neither this nor any other method will preserve them from shrinking.

The quality and well-seasoning of deals are very essential to the construction of buildings. They are employed in naked flooring, partitions, the boarding of floors, doors, windows, architraves, cornices, mouldings, dados, plinths, bases, surbases, wainscoting, linings, columns, pilasters, chimney-pieces, &c.

White deal should only be used for inside work, as in bed-chambers; it is less liable to shrink than yellow, and being a cheaper article, is to be preferred in panelling. Yellow deal, on account of its hardness, from being saturated with turpentine, is more fit to endure violence and exposure to the weather.

DEBASED, a term applied to that style of English architecture, so to speak, which succeeded the Late or Perpendicular Gothic, and in which some peculiarities of the Italian style began to be introduced. For more detailed information, *See* Gothic Architecture.

DECAGON (from δεκα, *ten*, and γωνία, an *elbow* or *corner*) a plane figure, with ten sides and angles. If all the sides and angles be equal, it is called *a regular decagon*, and may be inscribed in a circle: the method is thus: first describe a pentagon, as is shown under that article; bisect each of the arcs, of which the sides of the pentagon are chords; join every point of bisection to the extremity of each adjacent chord, and the decagon will be completed.

If the side of a regular decagon be 1, its area will

$$\text{be } \frac{5}{2}\left(5+2(5)\right)^{\frac{1}{2}}=7.6942088.$$

To find the area of a regular decagon: multiply the square of the side by 7.6942088, and the product will give the area: or, for practical use, multiply the square of the side by 7.6942.

Example. What is the area of a decagon, the side of which is 25 feet?

```
      25
      25
     ----
     125
     50
     ----
     625
  7.6942
  -------
    1250
   2500
  5625
 3750
4375
-----------
4808.8750 equal the area required.
```

This figure may also be measured by the general rule of finding the superficial content of any polygon whatever. *See* Polygon.

DECAHEDRON (Greek, δεκα, *ten*, and εδρα, *a base*.) A solid figure contained by ten sides.

DECAMETRE (Greek, δεκα, *ten*, and μετρον, *measure*,) a French linear measure containing ten metres, and equal to 393.71 English inches.

DECANICUM, a prison in which ecclesiastical offenders were confined.

DECASTYLE, or Decastylos (from the Greek, δεκα, *ten*, and ϛυλος, *a column*) a colonnade, or front of a portico, consisting of ten columns.

DECEMPEDA (from the Greek, δεκαπους; or from the Latin, *decem*, ten, and *pes*, *pedis*, foot) a ten-foot rod, used by the ancients: the foot was subdivided into twelve inches, and each inch into ten digits. This rod was used by architects to give the proper dimensions and proportions to their buildings.

Horace (lib. ii. od. 15) blaming the magnificence and delicacy of the buildings of his time, observes, that it was otherwise in the times of Romulus and Cato; that in the houses of private persons, there were not then known any porticos measured out with the decempeda, nor turned to the north to take the cool air.

The decempeda was also used in land-measuring, in the same manner as our chain.

DECIMAL (from the Latin, *decimus*) any number increasing by the order of tens.

Decimal Arithmetic, the art of computing by fractions whose denominator is 10, 100, &c. Decimal fractions differ from vulgar fractions in this; that the denominator is not written; instead of writing $\frac{4}{10}$, or $\frac{15}{100}$, the fraction would be written decimally, .4 or .15. The decimal point before it is used to distinguish it from whole numbers.

To reduce any vulgar fraction to a decimal, say,

As the denominator of the vulgar fraction
is to the denominator of the decimal,
so is the numerator of the vulgar fraction
to the numerator of the decimal.

Example. To reduce $\frac{2}{3}$ to a decimal fraction, whose denominator is 10.

```
It will then be as 3 : 10 : : 2
                          10
                         ----
                       3) 20
                         ----
                           6
```

so that 6 is the numerator required: but then there is a remainder of 2, consequently the numerator is more than 6, but less than 7; therefore $\frac{6}{10}$ is the nearest decimal fraction, whose numerator consists of a single unit. In order to come nearer to the truth, we must then suppose the denominator of the decimal to be divided into more parts, say 100.

```
Then again 3 : 100 : : 2
                        2
                     -----
                   3) 200
                     -----
                       66
```

but here is still a remainder of 2, that is, 66 is too small and 67 too great, therefore the decimal fraction $\frac{66}{100}$, is still too small; 66 is, however, a greater portion of 100, than 6 is of 10: we have therefore come nearer to the truth in the latter operation than in the first. We shall thus find, that if the number arising by multiplying the denominator of the decimal fraction by the numerator of the vulgar fraction, be not divisible by the denominator of the vulgar fraction, an increase of the denominator of the decimal will give a more

exact portion of the unit, than when fewer figures are used; and thus, if worth the trouble, the numerator of a decimal fraction may be found to any degree of exactness at pleasure, by augmenting the number of figures in the denominator, either till the division terminate, or till as many figures be found as will render the operation sufficiently exact for the intended purpose.

A decimal fraction may be sufficiently denoted, by throwing away the denominator, and using any character or mark instead of it, since the denominator is always 1, followed by one, two, three, or a series of ciphers, which is the only thing that is variable; to ascertain this point, the number expressed by the numerator, is always less than the denominator, and always consists of as many figures as there are ciphers; therefore, if a point be placed before the numerator of a decimal fraction, it will show that the number following it is a decimal fraction, and by reckoning a cipher for every figure, and supposing unity placed before them, the number thus expressed will show how many decimal parts the unit is divided into, and the figures themselves that portion of these parts taken.

Thus $\frac{6}{10}$ is represented by .6
$\frac{66}{100}$ " " .66
$\frac{785}{1000}$ " " .785
$\frac{85}{1000}$ " " .085

But instead of saying 66 hundredths, 785 thousandths, &c., say, as in the second, 6 tenths and 6 hundredths; as in the third, 7 tenths, 8 hundredths and 5 thousandths; and as in the fourth, 8 hundredths and 5 thousandths, as the cipher, 0, occupies the place of tenths;

$$\text{for} \quad \frac{6}{10}+\frac{6}{100}=\frac{66}{100}$$

$$\text{and} \quad \frac{7}{10}+\frac{8}{100}+\frac{5}{1000}=\frac{785}{1000}$$

$$\text{also} \quad \frac{8}{100}+\frac{5}{1000}=\frac{085}{1000}$$

The point is not only useful in marking the following number to be a decimal fraction, but is likewise necessary in separating the decimal parts from integers, when both are concerned.

From what has been said, it is observable that decimal fractions decrease in the same order from unity towards the right hand, that integers increase towards the right.

Thus, in 348.5683, unity is the place where the numbering commences both for integers and for decimals; going over the places of the integers, we have units, tens, hundreds, 348; then, numbering the decimals, we have units, tenths, hundredths, thousandths, ten thousandths, which is 5 tenths, 6 hundredths, 8 thousandths, and 3 ten thousandths; in this notation of the fractions, the unit's place was not reckoned, as being already counted into the whole numbers.

Supposing now, that the notation is completely understood, we will proceed to the reduction of decimal fractions.

To reduce a vulgar fraction to a decimal: set down the numerator of the fraction, with a point upon the right side of it, add as many ciphers in succession, towards the right-hand, as may be thought necessary; then, if the denominator consist of one single figure, or of two, not exceeding 12, draw a horizontal line below the row of figures so set down, and a vertical line upon the left side of the left-hand figure: set down the denominator upon the left of this line, proceed as in short division, placing a point under the other, then if the succeeding figures towards the right begin under the first figure after the point, these figures will be the decimal, but if not, the number corresponding to the upper row must be made out, by adding a cipher to the left hand.

Example I. Required the decimal of $\frac{1}{4}$.

```
4) 1.00
   ----
    .25 the decimal required.
```

Example II. Required the decimal of $\frac{1}{2}$.

```
2) 1.0
   ---
    .5 the decimal required.
```

Example III. Required the decimal of $\frac{3}{4}$.

```
4) 3.00
   ----
    .75 the decimal required.
```

The reader who wishes to employ decimals in his calculations, should have the decimals .25, .5, .75, of $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, fixed on his memory.

Example IV. Required the decimal of 1 inch in terms of a foot. Here 1 inch is the twelfth part of a foot, therefore the vulgar fraction is $\frac{1}{12}$.

```
12) 1.00000
    -------
     .08333
```

Example V. Required the decimal of 2 inches. Now 2 inches is $\frac{2}{12}$ or $\frac{1}{6}$; therefore

```
12) 2.00000    or    6) 1.00000
    -------             -------
     .16666              .16666
```

Example VI. What is the decimal of 3 inches? 3 inches is equal to $\frac{3}{12}$ or $\frac{1}{4}$, therefore the decimal will be .25, as above.

Example VII. Required the decimal of 4 inches. 4 inches is equal to $\frac{4}{12}=\frac{1}{3}$, therefore,

```
12) 4.00000    or    3) 1.00000
    -------             -------
     .33333              .33333
```

In this manner, the decimals for every number of inches under twelve are to be found, as the following table shows:

The decimal of 1 inch	=	.08333
2	=	.16666
3	=	.25
4	=	.33333
5	=	.41666
6	=	.5
7	=	.58333
8	=	.66666
9	=	.75
10	=	.83333
11	=	.91666

In most practical cases, three figures of decimals will be found sufficient.

When inches, seconds, thirds, &c. are to be reduced to a decimal, the best method is to reduce the feet, inches, &c. to the last denomination, then divide as often by 12 in succession as there are denominations, and the last quotient will be the decimal required.

Example I. Required the decimal of 9 firsts, or inches, and 6 seconds.

Now here are two denominations, therefore

```
     9 6
     12
    ----
12) 114 seconds in the whole.
    ----
12)  9.5
    ----
    7.9166 the decimal required.
```

Example II. To find the decimal of 5 seconds and 4 thirds.

Now in this example, there are three places of duodecimals, therefore

```
     0 5 4
       12
    ------
12) 64 number of thirds in the whole.
    ------
12)  5.33333
    --------
12)   .44444
    --------
      .03703
```

And thus for any other number of denominations whatever.

If each foot of our measuring-rules for taking the lineal dimensions were divided into ten parts, instead of twelve, and each of these ten parts again into ten others, we should have no occasion for reduction of decimals, as the rule itself would give the decimal. In most cases we should not then have occasion to work with more than two places of decimals; the tenth part of the tenth part, that is, the hundredth part of a foot, is very nearly equal to the eighth part of an inch, or the ninety-sixth part of a foot, being only a small matter less than the eighth of an inch. Were measuring-rules thus divided, the work by decimals would be much shorter than any other denomination whatever. The principal reason of operations in measuring by decimals being longer than duodecimals, arises from the necessity of reducing the duodecimals to decimals, and this in many cases cannot be done with the same accuracy, without having four or five denominations. In practical cases there are never more than three places of duodecimals, and if rules were divided decimally, there would not be more than three places.

A decimal part of a foot being given, to find its equivalent in duodecimals.

Multiply the decimal by 12, cut off as many decimals from the product as there are places of figures in the multiplicand, from the right-hand to the left, and the figure or figures remaining on the left, if any, will show the number of inches: multiply the number of decimals so cut off, if any, again by 12, and cut off as many figures from the left-hand of the new product as there are decimal places in the multiplicand, and the remaining figures on the left will show the seconds, if any. Proceed in this manner as often as there is a remainder, or as often as may be thought necessary to obtain a sufficient degree of accuracy, and the places cut off will be equivalent to the given decimal, if no remainder, and very nearly so if there is, but in this case something less.

Example. Reduce .44005 of a foot to a decimal.

```
 .44005
     12
 -------
5.28060
     12
 -------
 3.3672
     12
 -------
 4.4064
     12
 -------
 4.8768
```

To add decimals; write down the several parts under their respective denominators, viz., all the points in a vertical line, the tenths in a succeeding vertical line, and so on; add the several columns, as in common addition, from right to left; place a point under the column of points, or cut off as many decimal parts from the right-hand figure towards the left, as there are columns, and the figure or figures upon the left-hand side of the point, if any, will be integers, and those upon the right-hand side of the point will be decimals.

Example I. Add the following decimals together, viz., .7854, .07958, .5236.

```
 .7854
 .07958
 .5236
 -------
1.38858 the sum required.
```

To subtract decimals; place the numbers as in addition, the less under the greater, and perform the operation as in subtraction of integers.

Example I. Subtract .25 from .75.

```
.75
.25
---
.50 the number required.
```

If the parts of a foot are given in feet, inches, &c., they must be reduced to the farthest denomination from the place of feet.

To multiply in decimals, proceed as in multiplication of integers, and point as many figures, beginning with the first figure from the right in the product, as the number of decimals in both factors; and the remaining figures, if any, upon the left-hand, will be integers; but if there are not as many figures in the product as in both, the deficiency must be made up by the addition of one or more ciphers.

Example I.

```
Multiply .9087
by        .852
      --------
         18174
        45435
       72696
      --------
Product .7742124
```

In large decimals, the work may be contracted thus: Write the units' place of the multiplier under that place of the decimals in the multiplicand, whose place you would reserve in the product; write the other figures in the multiplier in a contrary order.

Begin with the figure of the multiplier nearest the right hand, and multiply by the next figure towards the right of it, in the multiplicand, if any; and if this product be five, or above five, in the number of tens in the product, carry one more than there are tens in the last product to the next product; then set down the overplus above the tens for the first figure, and carry the tens to the next place, and proceed through the line as in common multiplication. Proceed with every other line in the same manner, observing, however, to place the first figure of every line directly under the first figure of the last line, and the product so found will be the answer.

Example I.—What is the product of .9087 multiplied by .852, in order to retain four places of decimals?

```
By contraction.                      By the common method.
 .9087                                    .9087
 258.0                                     .852
 -----                                 --------
  7270 = 908 × 8 + 6                      18172
   454 =  90 × 5 + 4                     45435
    18 =   9 × 2 + 0                    72696
 -----                                 --------
 .7742                                 .7742122
```

In this example, the multiplier being placed as directed, begin with 8, the first figure of the multiplier, and multiply it by 7, the next figure to the right of it in the multiplicand, and the product is 56, which is more than 5 above 5 tens, therefore carry 6: multiply 8 by the next figure, 8 towards the left, the product is 64, and 6 carried, makes 70, set down a cipher for the first figure, and carry 7 to the next; proceed thus for the whole line, and 7270 will be the product. Proceed with the remaining figures of the multiplier, in the same manner, writing down the left-hand figures of every row under each other.

To divide a decimal or mixed number by a decimal or mixed number: divide as in whole numbers, and cut off as many figures from the right-hand of the quotient as the decimal places of the dividend exceed those of the divisor.

If the number of figures in the quotient be less than the excess of the decimal figures in the dividend above those of the divisor, the defect must be supplied by prefixing ciphers on the left hand. Should there be a remainder, annex ciphers to it, and thus the quotient may be carried to any degree of exactness, observing, however, that every cipher annexed in carrying out the work, must be accounted a decimal place in the dividend.

Example I.—Divide 43.95 by 5.

```
.5)43.95
   -----
    8.79 the quotient required.
```

Example II.—Divide 4.368 by .0078.

```
.0078)4.3680 (560
       390
       ---
       468
       468
       ---
       ..0
```

Decimal Scale, a scale divided into tenths. Scales thus divided are much used in designs. A $\frac{1}{4}$ inch scale is that wherein the $\frac{1}{4}$ inch is divided into ten parts: a $\frac{1}{2}$ inch scale is when the $\frac{1}{2}$ inch is divided into ten equal parts. One drawing may be made greater or less than another, by using two different scales made to the proportion of each drawing; but the best method of reducing or enlarging drawings, is by means of a pair of proportional compasses, which give both greater accuracy and expedition, with much less trouble, than working by scales.

DECIMETRE, a French linear measure equal to the tenth part of a metre, or 3.9371 English inches.

DECLINATION, of the Doric mutules, is the acute angle which the planes of the wall and soffit make with each other, by which the soffit is lower at its projecting extremity, than in the receding extremity, whence it commences. All the ancient examples of the Doric order have declining mutules.

DECLINATOR, an instrument used in dialing, whereby the declination, inclination, and reclination of planes are determined.

DECLINING DIALS, are those which either cut the plane of the prime vertical circle, or the plane of the horizon, obliquely.

The use of declining vertical dials is very frequent, because the walls of houses whereon dials are commonly drawn, generally decline from the cardinal points. Incliners and recliners are very rare, and more particularly decliners.

DECOR, a term used by Vitruvius, signifying *propriety*, arising either from disposition of the parts of an edifice, or from due observance of custom. *See* Decorum.

DECORATED, the title given to the most perfect style of Gothic architecture, which prevailed during the reigns of the first three Edwards, from the close of the thirteenth century. It is otherwise named the *middle-pointed*, or *pure Gothic.*

The various styles of Gothic architecture are so implicitly connected the one with the other, that it has been deemed advisable, at the risk of extending the article to a greater length than is customary in works of this nature, to consider them all under one head. *See* Gothic Architecture.

DECORATION, anything that adorns or enriches any part of an edifice. A tasteful combination of ornamental details employed in the enrichment of a building.

True decoration consists not in the mere addition of ornament, but rather in its appropriate and judicious application. Decoration, when artistically applied, possesses not only richness, but also meaning, not only a body, but a soul; it delights the eye, and at the same time, engages and instructs the mind. No artists, perhaps, so highly excelled in the just and tasteful employment of decorative detail, as did those of what are vulgarly termed the dark ages; in the glorious monuments of their skill, which have been preserved to us, we find specimens of the most delicate enrichment, all of which exhibit the reasonableness of its introduction; and the majority, a depth and tone of feeling rarely to be met with in other works.

The application of the Classic orders, however, as a means of decoration, is frequently resorted to, and not without success; they may be applied both internally and externally, and are themselves likewise frequently charged with further decorations.

Plain surfaces, when very extensive, are often decorated with paintings.

DECORATION EXTERNAL, the Building act, (7 and 8 Victoria, cap. 84), requires, that in external decorations, every coping, cornice, facia, window-dressing, portico, balcony, balustrade, or other external decoration or projection whatsoever, to any building now or hereafter to be built, or to any addition or enlargement of any such building, shall externally be of brick, stone, burnt-clay, or artificial stone, stucco, lead, or iron; except the cornice and dressings to shop-windows: and it is further provided with regard to buildings hereafter to be built or rebuilt, in reference to projections therefrom:—

As to copings, parapets, cornices to overhanging roofs, blocking-courses, cornices, piers, columns, pilasters, entablatures, facias, door and window-dressings, or other architectural decorations, forming part of an external wall, all such may project beyond the general line of fronts in any street or alley, but they must be built of the same materials as are by this act directed to be used for building the external walls to which such projections belong, or of such other proper and sufficient materials, as the official referees may approve and permit.

And as to all balconies, verandas, porches, porticos, shop-fronts, open inclosures of open areas, and steps and water-pipes, and to all other projections from external walls not forming part thereof, every such projection (except part of shop-fronts, and the frames and sashes of the windows and doors, in reference to the necessary wood-work thereof) may stand beyond the general line of fronts in any street or alley, but they must be built of brick, stone, tile, artificial stone, slate, cement, or metal, or other proper and sufficient fire-proof materials; and they must be so built as not to overhang the ground belonging to any other owner, nor so as to obstruct the light and air, or be otherwise injurious to the owners or occupiers of the buildings adjoining thereto on any side thereof.

Projections from walls of buildings over public ways.

And with regard to all buildings hereafter to be built or rebuilt, in reference to projections from the walls of such buildings, including-steps, cellar-doors, and area inclosures, the walls of all such buildings must be set back, so that all projections therefrom, and also all steps, cellar-doors, and area inclosures, shall only overhang or occupy the ground of the owner of such building, without overhanging or encroaching upon any public way.

Projected buildings beyond the general line of buildings, and from other external walls.

And with regard to buildings already built, or hereafter to be rebuilt, as to bow windows or other projections of any kind.

Such projections must neither be built with nor be added to any building on any face of an external wall thereof, so as to extend beyond the general line of the fronts of the houses (which general line may be determined by the surveyor, except so far as is herein before provided with regard to porticos projected over public ways; and with regard to projections from face-walls and shop-fronts, not so as to overhang the ground belonging to any other owner, nor so as to obstruct the light and air, or be otherwise injurious to the owner or occupiers of the buildings adjoining thereto on any side thereof.

Projections from insulated buildings.

Provided always, with regard to any insulated buildings, that if the projection be at the least 8 feet from any public way, and if they be at least 20 feet from any other building not in the same occupation, then such projections are excepted from the rules and directions of this act.

Wooden shop-fronts and shutters.

And with regard to shop-fronts and their entablatures, their shutters, and pilasters and stall-boards made of wood.

If the street or alley in which such front is situate, be of less width than 30 feet, then no part of such shop-front must be higher in any part thereof than 15 feet; nor must any part, except the cornice, project from the face of a wall, whether there be an area or not, more than 5 inches; nor must the cornice project therefrom more than 13 inches.

If the street or alley be of a greater width than 30 feet, then no part of such shop-front, except the cornice, must project from the face of a wall, whether there be an area or not, more than 10 inches; nor must the cornice project therefrom more than 18 inches.

And the width of such street or alley must be ascertained by measuring the same, as directed by the act.

And the wood-work of any shop-front must not be fixed nearer than four and a half inches to the centre line of a party wall.

And with regard to such wood-work, if it be put up at such distance of four and a half inches, then a pier or corbel built of stone or of brick, or other incombustible material, and of the width of four and a half inches at the least, must be fixed in the line of the party wall, so as to be as high as such wood-work, and so as to project one inch at the least in front of the face thereof.

And the height of every shop-front must be ascertained by measuring from the level of the public foot pavement in front of the building.

And every sign or notice-board fixed against or upon any part of any house or other building standing close to any public way, must be so fixed that the top shall be within 18 feet at the most above the level of such public way.

DECORATION OF THE SCENERY OF A THEATRE, is the representation of the subject by which the scenes are charged.

The ancients used two kinds of decoration in their theatres, the one called *versatiles*, with three sides of faces, which were turned successively to the spectators; the other, called *ductiles*, showing a new decoration, by drawing or sliding another before it.

The latter kind is still in use, and the change is almost made in an instant; whereas the ancients were obliged to draw a curtain whenever a change of decoration was required.

DECORUM, or DECOR, in architecture, is the suitableness of a building, and the several parts and ornaments thereof, to the station and occasion. "It consists," says Vitruvius, (book i. chap 2.), "in the proper appearance of a work, and its being compounded of approved and authorized parts. This has regard, either to station, which the Greeks call *thematismos*, custom, or nature. To station, when temples which are erected to Jove the Thunderer, the heavens, the sun, or the moon, are built uncovered and exposed to the air, because the influences and effects of those deities are perceived in the open air; when to Minerva, Mars, Hercules, Doric temples are built; for, on account of the attributes of these deities, edifices constructed without delicacy are most suitable. To Venus, Flora, Proserpine, and the nymphs of the fountains, the Corinthian kind are erected with propriety; for by reason of the delicacy of those goddesses, the graceful, gay manner, with foliage and ornamented volutes, give a due decorum to the work. To Juno, Diana, Bacchus, and such other deities, Ionic temples are constructed, as holding a position between the two; for being tempered of the severity of the Doric, and the tenderness of the Corinthian, they become most suitable. Decor, with regard to custom, is observed when the internal parts of edifices being magnificent, the accesses are also made suitable and elegant: for, if the interior parts be elegant, and the approaches mean and ignoble, it will not have decor. So, likewise, if dentils be carved in the cornice of the Doric epistylium, or in the abacus of the capital, or if triglyphs be represented in the epistylium of Ionic columns, transferring the characteristics of one kind of work to another; it offends the eye, because custom has established a different order of things.

"Decor, with regard to nature, consists in all temples being placed in a salutary situation, with fountains of water in the places where the fane is built; but especially the temples of Æsculapius, of Health, and such deities, by whose healing influences numbers of sick appear to be recovered. For the diseased bodies being removed from an unhealthy to a healthy situation, and the salutiferous water of the fountains being administered, they are soon restored. By this means it will happen, that the natural effects of the place will increase the received opinion of the power of the divinity.

"Decor, with regard to nature, is also observed, when chambers and libraries receive their light from the east; baths, and winter apartments, from the west; picture-galleries, and such apartments as require as steady light, from the north; because that region of the heavens is rendered neither lighter nor darker by the course of the sun, but is equal and immutable the whole day."

DEDICATION, the act of consecrating a temple, altar, statue, palace, &c., to the honour of some deity.

DEFINITION, (*definire*, to mark out a boundary), is the process of stating the exact meaning of a word, by means of other words, or an enumeration of the principal attributes of a thing, in order to convey or explain its nature; thus, a circle is defined to be a figure whose circumference is every where equidistant from its centre. Wolfius defines a real definition to be a distinct notion, explaining the *genesis* of a thing; that is, the manner wherein the thing is made, or

done; such is that of a circle, whereby it is said to be formed by the motion of a right line round a fixed point; on which footing, what was before instanced as a real definition of a circle, amounts to no more than a nominal one.

This notion of a real definition is very strict and just; and affords a sufficient distinction between a real and a nominal one. But though it has the advantages of analogy, distinctness, and convenience, on its side; yet being only itself a nominal definition, *i. e.*, a definition of the term *real definition*, we must consider it in the light of an idea fixed arbitrarily to that word, and which Wolfius always denotes by that word in the course of his book.

Of the parts enumerated in a definition, some are common to other things beside the thing defined; others are peculiar thereto: the first are called *the genus*, or *kind;* and the second, *the difference*. Thus, in the former definition of a circle, by a figure whose circumference is everywhere equidistant from its centre; the word *figure* is the kind, as being a name common to all other figures as well as to the circle; the rest the difference, which specifies or distinguishes this figure from every other. And hence arises that rule of F. de Colonia, for the making of a definition. "Take," says he, "something that is common to the thing defined with other things, and add to it something that is proper, or peculiar to it; *i. e.*, join the genus and specific difference, and you will have a definition." The special rules for a good definition are these:—1. A definition must be universal or adequate, that is, it must agree to all the particular species, or individuals, that are included under the same idea. 2. It must be proper, and peculiar to the thing defined, and agree to that alone. These two rules being observed, will always render a definition reciprocal with the thing defined, that is, the definition may be used in the place of the thing defined; or they may be mutually affirmed concerning each other. 3. A definition should be clear and plain; and, indeed, it is a general rule concerning the definition both of names and things, than no word should be used in either of them which has any difficulty in it, unless it has been before defined. 4. A definition should be short, so that it must have no tautology in it, nor any words superfluous. 5. Neither the thing defined, nor a mere synonymous name, should make any part of the definition.

DEFLECTION, a term applied to the distance by which a curve departs from a straight line, or from another curve. It is used where any "*bending off*" takes place; the word deflection, in fact, means "bending off."

DEINCLINING DIALS, such as both decline and incline, or recline.

DELUBRUM, in Roman antiquity, a temple with a large space of consecrated ground round it. Also that portion of a temple in which the altar or idol was placed. *See* TEMPLE.

DEMI-RELIEVO, a term applied to that class of sculpture in which the figures are raised only halfway above the surface.

DEMONSTRATION, (from the Latin) in mathematics, a method of reasoning, whereby the truth of an assertion is shown by two, or a series of propositions, whose truth is already established.

Thus the 47th proposition of the first book of Euclid demonstrates a certain property of a right-angled triangle, on the supposition:—1, that all the preceding propositions are true; 2, that the axioms used in geometry, whether expressed or implied, are true also. It makes the consequence as certain as the premises, by means of the indubitable character of the connecting process. This strict use of the term demonstration belongs to the science of logic, which is the art of demonstrating from premises, without reference to the truth or falsehood of the premises themselves. In effect, the demonstrations of mathematicians are no other than series of enthymemes; everything is concluded by force of syllogism, only omitting the premises, which either occur of their own accord, or are recollected by means of quotations. To have the demonstration perfect, the premises of the syllogisms should be proved by new syllogisms, till at length you arrive at a syllogism, wherein the premises are either definitions, or identical propositions.

Indeed, it might be demonstrated, that there cannot be a genuine demonstration, *i. e.*, such a one as shall give full conviction, unless the thoughts be directed therein according to the rules of syllogism. Clavius, it is well known, resolved the demonstration of the first proposition of Euclid into syllogism: Herlinus and Dasipodius demonstrated the whole first six books of Euclid, and Henischus, all arithmetic, in the syllogistic form.

Yet the generality of persons, and sometimes even mathematicians, imagine, that mathematical demonstrations are conducted in a manner far remote from the laws of syllogism; so far are they from allowing that those derive all their force and conviction from these. But men of the greatest ability have taken our view of the question. M. Leibnitz, for instance, declares that demonstration to be firm and valid, which is in the form prescribed by logic; and Dr. Wallis confesses, that what is proposed to be proved in mathematics is deduced by means of one or more syllogisms; the great Huygens, too, observes, that paralogisms frequently happen in mathematics, through want of observing the syllogistic form.

Problems consist of three parts: a proposition, resolution, and demonstration.

In the proposition is indicated the thing to be done.

In the resolution, the several steps are orderly rehearsed, whereby the thing proposed is performed.

Lastly, in the demonstration, it is shown, that the things enjoined by the resolution being done, that which was required in the proposition is effected. As often, therefore, as a problem is to be demonstrated, it is converted into a theorem; the resolution being the hypothesis, and the proposition the thesis; for the general tenor of all problems to be demonstrated is this: that the thing prescribed in the resolution being performed, the thing required is done.

The schoolmen make two kinds of demonstration: the one τȣ διοτι, or *propter quod;* wherein an effect is proved by the next cause; as when it is proved, that the moon is eclipsed because the earth is then between the sun and moon. The second, τȣ οτι, or *quia;* wherein the cause is proved from a remote effect; as when it is proved that fire is hot, because it burns; or that plants do not breathe, because they are not animals; or that there is a God, from the works of creation. The former is called *demonstration à priori*, and the latter *demonstration à posteriori.*

DEMONSTRATION, *Geometrical*, is that framed of reasonings drawn from the elements of geometry.

DEMONSTRATION, *Mechanical*, is that, the reasonings whereof are drawn from the rules of mechanics.

DENDERAH, the Tentyra of the ancients, a ruined town of Upper Egypt, celebrated for its temple, which is one of the most splendid remains of antiquity in all Egypt. Dr. Richardson, Belzoni, and others, have given descriptions of this temple, which the first-named traveller considers to have been erected in the period of the Ptolemies. Its remains occupy a vast extent of ground, and consist of various buildings, besides the temple itself. These are enclosed within a wall built of sun-dried bricks, in some places 35 feet high,

and 15 feet thick. The portico in front of the temple is formed of 24 columns, ranged in four rows, having quadrangular capitals, on each side of which is a colossal head, surmounted by another quadrangular member, containing in each face a temple doorway with two winged globes above, and other decorations. The shafts of the columns are cylindrical, and of equal diameter throughout. The whole height, including capital, &c., being a little above 48 English feet.

The front is adorned with a beautiful frieze, covered with figures, over the centre of which the winged globe is predominant. The walls, columns, ceilings, and also the interior chambers, are in the same manner covered with hieroglyphics and sculptures, in which the figure of Isis is repeated in numberless instances. The light in the chambers comes in through small holes in the wall; the sanctuary itself is quite dark. The ceiling of the portico is occupied by a number of figures, by some travellers supposed to be the signs of the zodiac, but with greater accuracy shown by Dr. Richardson and recent travellers and archæologists, to be merely a collection of mythological emblems, without any reference to astronomy.

On the ceiling of one of the apartments in the upper story, under the roof of the temple, there was another assemblage of mythological emblems, similar to those already mentioned, but fewer in number, and differently arranged. This was called a planisphere or zodiac, because in the middle of it figures resembling those usually adopted to represent the signs of the zodiac were observed. The opinion of well-informed travellers, however, with respect to this collection of figures, as to the former, is that it is only a representation of gods and goddesses, and religious processions, and has no astronomical meaning whatever.

The so-called circular zodiac, which was sculptured on a kind of sandstone, was cut out of the ceiling by a Frenchman, with the permission of the pasha, and conveyed to France; when it was purchased by the French government, and deposited in the Museum, at Paris.

DENDROMETER, (from δένδρον, *a tree*, and μετρεω, *I measure*), an instrument for measuring trees.

The same name has also been applied, though improperly, to instruments contrived for measuring distances and magnitudes from a single station.

DENTICLES. *See* DENTILS.

DENTILS, (from the Latin, *dens*, a tooth) a row of similar and equal solids in a cornice, disposed at equal intervals, each presenting four sides of a rectangular prism, the sides parallel to the vertical face, and the one parallel to the soffit, being attached to the vertical and horizontal planes of an internal right angle.

The surfaces of the vertical face are therefore all in the same plane: and those of the soffits are in the same horizontal plane.

The whole series of dentils in the same range, is called *the denticulated band.*

The proportions given by Vitruvius are, that "the denticulus is to be equal in height to the middle facia of the architrave, and its projection to be the same as its height; the width of the dentils is one-half of its height, and the interval between them two-thirds of this quantity."

The proportions of some of the best examples where dentils are to be found, are as follows:—

In the Ionic temple of Bacchus, at Teos, the dentils are in height about one-fourth of that of the cornice, exclusive of the inferior bead and fillet next to the architrave: the breadth of the dentils is about two-thirds of their height, and the breadth of the interval about two-thirds of that of the dentil: their projection is about one-fourth of the height of that part of the cornice between their soffits and the summit of the cornice: the angle is vacant.

The dentils in the Ionic order of the temple of Minerva Polias, at Priene, are something less than one-fourth of the height of the cornice, or nearly equal to two twenty-fifths of that of the entablature; their projection is three times the half of their height; their breadth, two-thirds of their height; the breadth of the interval, about four-fifths of that of the dentils: the corner is without a dentil, and the soffit over the vacant angle is enriched with a honeysuckle.

In the Corinthian order of the Choragic monument of Lyscirates, at Athens, the dentils of the cornice are in height nearly two-sevenths of that of the cornice, exclusive of the terminating ornament; their breadth is two-thirds of their height; and the interval between them, two-thirds of their breadth; the angle of the cornice at the dentil band is vacant.

In the temple of Jupiter Stator, at Rome, the height of the dentil is nearly one-fifth of the whole cornice; its breadth, two-thirds of its height; and the breadth of the interval, about one-half of that of the dentil; the angle of the dentil-band is filled with a dentil.

The reader who wishes to see the rules of Vitruvius, respecting the placing of dentils, may consult the article CORNICE.

In the frontispiece of the door-way of the Tower of the Winds, at Athens, the inclined cornices, as well as the level one, have dentils, contrary to the doctrine of Vitruvius.

In the interior cornice of the same tower, both dentils and modillions are employed; the dentils occupying the superior part of the cornice, agreeably to the Vitruvian theory, but contrary to every other antique example.

The only ancient example of the Doric order, in which dentils are to be found, is in the theatre of Marcellus, at Rome.

The examples of the Ionic order which have denticulated cornices, are, the temples of Bacchus, at Teos; of Minerva Polias, at Priene; the aqueduct of Adrian, at Athens; the temple of Fortune, and the theatre of Marcellus, at Rome; and the arch of Constantine; the temple of Concord, at Rome, has both dentils and modillions in the cornice.

The following edifices of the Ionic order, are without dentils in the cornice, viz., the Ionic temple upon the Ilissus, the temple of Minerva Polias, and that of Erechtheus, at Athens; and in the Coliseum, at Rome, the dentil-band is uncut. Examples of the Corinthian order, which have denticulated cornices, are, the monument of Lysicrates, the arch of Adrian at Athens, and the ruins at Salonica. Both dentils and modillions are to be found in the following Corinthian edifices: the temples of Jupiter Stator, and of Peace, the piazza of Nerva, and the baths of Diocletian, at Rome; the lower range of the interior, and the porticos of the temple of Jupiter, and the vestibulum to the peristylium, at Spalatro; all the ruined edifices at Balbec, and at Palmyra, excepting the interior order of the temple of the Sun, among the latter.

The following edifices of the Corinthian order have the dentil-band uncut, viz., the Coliseum, the portico of the Pantheon, the temple of Antoninus and Faustina, and the portico of Septimius Severus, at Rome.

Examples of the Composite order, which have denticulated cornices, are, the arch of Septimius Severus, and that of the Goldsmiths, at Rome, and the upper range of the temple of Jupiter, at Spalatro; but in the arch of Titus, at Rome, both modillions and dentils are to be found.

The frontispiece to the door-way of the Tower of the

Winds, at Athens, though it cannot be classed as a regular order, has dentils in the cornice.

A denticulated cornice is employed in the Caryatic portico of the temple of Pandrosus, at Athens.

Thus it may be observed, that dentils and modillions are frequently employed in Corinthian and Composite cornices; and sometimes both are omitted, as in the temple of Vesta at Tivoli, and in the temple of Antoninus and Faustina, and the little altars within the Pantheon, at Rome.

In very small work, it would be better to omit modillions and dentils: and, indeed, it is the opinion of some, that though the work be ever so large, it would be better to employ one of them only; as, were all the members to be admitted in a Corinthian cornice, and if the individual parts of the cornice bear the same proportion to the whole height, as in the Doric or Ionic orders, the cornice would either be too high for the entablature, or the entablature too high for the column; consequently, the cornice must either be too great a load for the entablature, or the entablature too great a load for the column; which, in either case, is contrary to the laws of strength: for it would be giving the greater burden to the slender column, and the lighter burden to the more massive. *See* CORNICE.

DEPARTMENT, (from the French) that part of an edifice destined to some peculiar purpose, as, in a palace, the department of a kitchen, of the stables, &c.

DEPÔT, (French) in military architecture, an edifice for the preservation and reservation of stores, provisions, &c., also a station for the reception and training of recruits.

A depôt should contain a great number of bomb-proof buildings, the lower tier of which should be reserved as store-rooms for provisions requiring to be kept cool, and, if possible, be below the surface of the area; the ground-floor should be allotted for artillery and ordnance-stores; the walls and piers being furnished with strong wooden battens (projecting a little, to obviate the danger of damp) for the support of muskets, carbines, pistols, swords, halberts, bayonets, pikes, and other descriptions of small-arms. The second floor should be devoted to the reception of camp-equipage, and the upper to the lodgment of ready-filled cartridges. The great magazines for powder should be separate: the whole of the principal body should be casemated for the accommodation of troops, and pierced through, perhaps masked, for the reception of heavy cannon. The out-works should be of the best materials, and constructed on the most compact system of defence.

DESCRIBENT, (from the Latin, *describo*, to describe) in geometry, a line or surface which produces a plain figure by motion.

DESCRIPTION, of a building, an explanation of all the materials, specifying their qualities, proportions, how used, sizes of timbers, &c.

The following articles are most frequently employed in buildings, in the carpenter's department:—

Carpentry.

- **Timber in foundations**
  - Piling
  - Planking
    - Spikes
- **Bonding**
  - Sleepers
  - Bond-timbers in brick walls
  - Templets
  - Wall-plates
    - Under-sleepers
    - Under-joists
    - Under-roof
  - Lintels
- **Common naked flooring**
  - Sleepers
  - Joists
    - Trimmers
    - Trimming-joists
    - Strutting-pieces
- **Framed naked flooring**
  - Girders
  - Binding-joists
  - Bridging-joists
- **Common roofing**
  - Rafters
  - Ceiling-joists, ties, or tie-beams
  - Collar-beams
  - Puncheons
  - Hips
  - Valleys
  - Ridge pieces
  - Beams for platforms
  - Beams for skylights
  - Boarding
    - for slates, $\frac{3}{4}$-inch thick
    - for platform, for gutters: $1\frac{1}{8}$-inch thick
    - Arris fillet
  - Bearers for gutters
- **Trussed roofing**
  - Wall-plates
  - Diagonal ties
  - Dragon-beams
  - Tie-beams
  - Pole-plates
  - Hammer-beams
  - Truss-posts
    - King-posts
    - Queen-posts
  - Braces
  - Struts
  - Auxiliary rafters, or principal braces
  - Studs
  - Principal rafters
  - Hip-rafters
  - Valley-rafters, or valleys
  - Collar-beams, or straining-beams
  - Purlins
  - Camber-beams
  - Straining-sill
  - Common rafters
  - Boarding, generally $\frac{3}{4}$-inch thick
  - Arris fillet, $\frac{3}{4}$-inch by 3 inches
- **Sound boarding**
  - Nails, what kind
  - Fillets, $1\frac{1}{2}$ inch by 1 inch, nailed at 1 foot distance
  - Boarding, $\frac{3}{4}$-inch thick, with or without nails
- **Nine-inch brickwork**
  - Wood bricks, $2\frac{1}{2}$ inches by 4 inches
- **Brick-nogging**
  - Quarterings
  - Nogging-pieces
  - Lintels
- **Common wooden partitions**
  - Sills
  - Quarterings
  - Top-pieces
- **Truss partitions**
  - Sills, or plates
  - Door-posts
  - Truss-posts
    - King-posts
    - Queen-posts
    - Side-posts
  - Braces
  - Inter-tie, or straining-piece
  - Common quarterings, $1\frac{1}{2}$ inch thick

- Battening for walls
  - Plugging, at what distances
  - Battens, 2 inches by $\frac{3}{4}$-inch
  - Nails
- Grounds
  - for windows, edge-chamfered or grooved
  - for mouldings
  - for chimneys
  - for doors
  - for cupboards
- Angle-staff
  - Square
  - Beaded
- Ribbing
  - Ceiling-joists
  - Bracketing $1\frac{1}{2}$ inch thick
- Lath
  - on walls
  - on ceilings
  - behind shutters
  - and back of skirtings

Joinery.

- Sash-frames
  - Pulley-pieces
  - Inside facings, or linings
  - Outside linings
  - Back linings
  - Heads
  - Sills
  - Beads
- Sashes
  - Primed
  - Glazed, with oil-putty
  - Pulleys
  - Weights
  - Lines of the best quality
- Skylights
  - Hatch windows
  - Square skylights
  - Polygonal skylights
  - Circular or elliptic conic skylights
- Boarding for floors (brads 19lb. per M.)
  - Boards
    - grooved and tongued, or straight-jointed
  - Battens
    - grooved and tongued, or doweled together
- Boarding for walls (used in shops, water-closets, &c. When less than the whole height a coping is used)
  - Plugs
  - Battens
  - Boards
  - Nails
- Cupboard linings
  - Sides
  - Backs
- Miscellaneous
  - Door stops
  - Shelving
  - Dado
    - Framed
    - Plain, glued together
- Door linings
  - Jambs
  - Soffits
- Doors
  - Stiles
  - Rails
  - Munnions, or
  - Mountings
    - (Stiles, Rails, Munnions, or Mountings:) Mouldings laid in or planted, or moulded on one or both sides of framing, or bead and flush, or bead and butt.
  - Panels, flat or raised, or with planted beads
- Dado
  - plain
  - framed
    - (plain, framed:) Keys
- Recess to windows
  - Backs
  - Elbows
  - Soffits
  - Boxings
  - Back-linings
- Shutters
  - Front shutters
  - Closers
- Mouldings
  - of interior doors, framed doors, linings, backs, elbows, soffits, and shutters, to be all similar.
- Finishings
  - Base of rooms
    - Skirtings
    - Base mouldings
  - Surbases
  - Architraves
    - single faced
    - double faced
    - Blocks to be used or not
  - Pilasters
    - plain
    - sunk
  - Facings
  - Belts
  - Skirtings
  - Wood moulding upon stone skirting
  - Jamb mouldings
  - Chimney-pieces
  - Hatch-boards
- Kitchen
  - Kitchen dresser
  - Belting round kitchen
  - Wired or latticed windows for larder
- Water-closet
  - Flap, clamps, as also the top seat
  - Riser, framed bead and flush
- Water conveyances
  - Troughs, with hooks and bolts
  - Water trunks
  - Cover for rain-water pipes
- Stair
  - Risers
  - Treads
  - Rail, of deal or mahogony.

A clause in specification, describing the quality of wood.

Joiner to take the plaster work off the plasterer's hand, or to make it good if damaged by his men.

Time of finishing the joinery.

DESCRIPTIVE CARPENTRY, the art of forming a diagram on a plane by the rules of geometry, in order to construct any piece of carpentry of a known property, from certain given dimensions of the thing to be constructed.

This branch is only the application of stereography to Carpentry: and, indeed, the only difference between stereography and descriptive carpentry, is, that in the former, the bodies are entire solids, but in the latter, the bodies to be formed consist of ribs, disposed in parallel lines or planes, or in lines tending to a point, or in planes tending to an axis; so that descriptive carpentry shows the methods of forming the separate pieces in order to construct the whole body or solid. Stereography is, therefore, not only employed in the construction of individual pieces, but also in the whole, when brought into a mass, or taken as one body. This branch is a necessary qualification to an architect, not only to enable him to anticipate the effect, but to judge of the propriety of the execution of any proposed work.

It is too often the case, that young men professing to be studying the science of architecture, will not submit to that which they are pleased to deem the drudgery of the profession. Instead of acquiring, by constant practice and studious diligence, the necessary elements of descriptive and constructive knowledge of the various parts of an edifice, they attempt, before they are qualified by such knowledge, to design edifices, fanciful in conception, as they would be ridiculous if executed.

The result of this want of careful training, is well described by Mr. Bartholomew, in the following passage:—" Taken

from school at an age in which he cannot have imbibed in any degree sufficient of a polite and liberal education, the architectural pupil, frequently with no knowledge whatever of geometry, never acquires any beyond the mere manual dexterity of drawing circular and plain lines; abandoned by his master while yet scarcely arrived at manhood, forced into premature and profitless practice with all the expenses of a separate establishment, it cannot be wondered at, that the adolescent architect sometimes has, in after-life, bitter cause to repent the circumstances and the rashness, which led him to acquire practical design and practical construction, solely by his youthful failures; for it is then, with deep repentance, that he perceives the confusion of styles into which he has fallen, the whole chronology of gothic arches which he has paraded in the same façade, the mixture of Roman forms and luxury with the severe and elegant simplicity of the Greeks; in many a breaking up and fracture, he has the mortification to find that inventions upon which he has relied for eternal duration, have not survived their inventor's ruin; that he has formed his pinnacles with graduated outlines, as if Rosslyn chapel or some other impure source were his only pursuit; he regrets that he has placed his columns opposite apertures, instead of opposite piers; he regrets that, from false bearing, want of plumb and equipoise, his work is so fractured, that even a man of more experience than himself cannot restore it; he perceives too late, that his patronage of mean and fragile stone, and pretended substitutes for it, his reliance on bad timber, has added something to the wreck of his country's architecture; he perceives with deep mortification, that his want of mathematical and mechanical skill, both theoretical and practical, has led him to perform that which a professor of more experience would avoid; broken arches, tie-less roofs, walls thrust from their right position, partitions falsely trussed, and groaning beneath loads which, formed otherwise, they might have borne unflinchingly, and a foundation which fails in all directions from want of sufficient spread to the footings, or from the building being carried up piecemeal, or from other causes—these are a few of the faults and disasters, which in after times make a precocious practitioner wish he had studied five or ten years more, before he had risked himself or his employer's property."

This was not the case formerly; men endeavoured in those days to qualify themselves for the practice of their profession, by long study, practice, and unceasing diligence.

Architects, among the ancients, were highly accomplished characters, being skilled in all the geometrical and mechanical knowledge of their time; and in this country they have had much claim to eminence as late as the reign of Queen Anne. Since that time, however, a gradual declension of the art is equally perceptible in all public edifices, as well as in all works of architectural literature.

Though travelling adds to the accomplishment of a judicious architect, it is among the least of the necessary qualifications; a careful observer will lay up greater stores of knowledge at home, than he who has travelled, with inferior abilities; and, indeed, if the architect have no farther views, than that of travelling, in order to produce what he calls drawings of taste, he will, in most instances, become ostentatious, and will ultimately lose the good opinion of his employers. Travelling improves the man of science, but inflates the sciolist with vanity, and renders him ten times more a subject of commiseration than before.

As those parts of carpentry which are objects of description, are placed under their proper denominations, the reader is referred to each particular term, for further information upon this useful subject.

DESCRIPTIVE GEOMETRY, the art of representing a definite body upon two planes, at right angles with each other, by lines falling perpendicularly to the planes from all the points of the concourse of every two contiguous sides of the body, and from all points of its contour; and, *vice versa*, from a given representation to ascertain the parts of the original object.

Descriptive geometry may therefore be considered synonymous with *orthographical* projection, upon which subject, with the exception of a treatise by Mr. P. Nicholson, (first published in 1795, and re-published with improvements in the year 1809), nothing had appeared in the English language, until the publication of this Dictionary.

About the year 1794, the celebrated Monge, who has been called the inventor of *descriptive geometry*, published in France his *Géométrie Descriptive*, one of the most elegant and lucid elementary works in existence. Previous to the appearance of this work, the science of perspective and many other applications of geometry to the arts, had required isolated methods of obtaining lines, angles, or areas, described under laws not readily admitting of the application of algebra, and its consequence, the construction of tables. The descriptive geometry of Monge is a systematized form of the method by which a ground-plan and an elevation are made to give the form and dimensions of a building. The projections of a point upon two planes at right angles to each other being given, the position of the point itself is given. From this it is possible, knowing the projections of any solid figure upon two such planes, to lay down on either of those planes, a figure similar and equal to any plane section of the solid.

This necessary and neglected part of education, had been also much cultivated by Mr. Nicholson, and with such success, that his works have always been referred to by succeeding writers as authorities. In addition to the treatise above mentioned, and also some parts of the carpentry in Rees' Cyclopædia; the numerous valuable articles in this Dictionary attest the sound practical knowledge of the writer, and his perfect acquaintance with the subjects on which he has written. It is due to his memory, to state that he had at that time no knowledge of any foreign work on Descriptive Geometry, and that the treatise by Monge did not fall into his hands until the year 1812. While strongly recommending that work, however, to the study of all those who are desirous of attaining truth in delineation, he considers his own views, differently conceived, as undoubtedly they were, from those of Monge, to have equal claims to originality.

As we are desirous of omitting nothing that may tend to enlarge the bounds of science, we shall here insert so much of Monge's work as we conceive to be conducive to this end, referring Mr. Nicholson's own ideas on this branch of geometry, to the article PROJECTION, a name better understood in this country than that of Descriptive Geometry.

To facilitate the knowledge of this subject, the reader should be well acquainted with the eleventh book of *The Elements* of Euclid, which treats particularly of planes, and the manner in which solids are constituted.

"*Figure* 1.—If from all the points of an indefinite right line, however situated in space, we imagine perpendiculars to be dropped upon a given plane, L M N O, all the points of these perpendiculars will fall upon the plane in another indefinite right line, *a b*, for they will be all comprised in the plane described by A B, perpendicular to the plane L M N O, and can only meet the latter in the line of intersection common to both planes, which is a right line.

"The right line *a b*, which passes through the projections

of all the points of the right line A B, upon the plane L M N O, is called the projection of the right line A B upon this plane.

"As two points are sufficient for determining the position of a right line; it is only necessary, in constructing the projection of a right line, to construct the projections of two of its points, and the line which they describe will be the required projection.

"Hence it follows, that if the proposed right line be perpendicular to the plane of projection, its projection will be reduced to a single point, which will be that in which it falls upon the plane.

"*Figure* 2.—The projections $a\ b$, $a'\ b'$, of the same indefinite right line, A B, being given upon two planes, not parallel, L M N O, L M P Q, this right line is determined; for, if from one of the projections, $a\ b$, we imagine a plane perpendicular to L M N O, the position of this plane being known, it would necessarily pass through the right line A B. The position of this right line, which is found at once upon both the known planes, consequently at their mutual intersection, is therefore absolutely determined.

"What we have just stated is to be understood as independent of the planes of projection, and takes place, whatever may be the angle formed by the two planes. But if the angle formed by the two planes of projection be very obtuse, that formed by their perpendiculars will be very acute: very trifling mistakes in this respect, will, in practice, lead to very grave errors in determining the position of the right line. To obviate this cause of inaccuracy, at least in the absence of better means, it is usual to have the planes of projection perpendicular to each other: besides which, as most artists, who use projections, are familiar with the position of a horizontal plane and the direction of a plumb-line, they generally represent one plane of projection as horizontal, and the other vertical.

"The necessity of representing, in drawings, the two projections upon the same sheet, and in larger operations upon the same area, has farther determined artists to represent the vertical plane as turning and folding down, as upon a hinge, at its intersection with the horizontal plane, so as that the two may form but one plane, upon which they construct their projections.

"The vertical projection is thus, in fact, traced upon a horizontal plane, and it must ever be kept in mind, that it must be corrected and put in its place, by turning it one-fourth of a revolution round its intersection with the horizontal plane: to do which accurately, care must be taken to trace this intersection very plainly upon the design.

"Thus, in *Figure* 2, the projection $a'\ b'$ of the right line A B, could not be drawn upon a real vertical plane; but if we conceive the plane to be turned about the right line L M, so as to bring it in contact at L M P′Q′, we shall readily execute the vertical projection $a'\ b'$.

"Besides the facilities of execution presented by this disposition, it possesses the additional advantage of abridging the labour of projections. Thus, suppose the points a, a', to be the horizontal and vertical projections of the point A, the plane indicated by the right lines A a, A a', will be perpendicular to the two planes of projection at the same time, because it passes along the right lines perpendicular to them: consequently, it will be perpendicular to their common intersection L M; and the right lines a C, a' C, according to which they cut these two planes, will be themselves perpendicular to L M.

"Now, if the vertical plane be turned about L M, as upon a hinge, the right line a' C, still continues perpendicular to L M; and the case is still the same, when the vertical plane, laid down, assumes the position C a''. Thus the two right lines a C, C a'', passing both by the point C, and being both perpendicular to L M, are in prolongation to each other; the case is similar with the right lines b D, D b'', as to every other point, as B. Hence it follows, that when we have obtained the horizontal projection of a point, the projection of this same point upon the vertical plane, supposed to be laid down, will be in the right line drawn along by the horizontal projection perpendicularly to the intersection, L M, of the two planes of projection, and this reciprocally.

"This result very frequently occurs in practice.

"We have hitherto considered the right line, A B, *Figure* 2, as indefinite; in which case we should only have to do with its direction; but we must now consider it as terminated by the points A B, which will bring us to take its extent into our calculation. We shall, therefore, examine how this may be deduced from a knowledge of its two projections.

"When a right line is parallel to one of the planes on which it is projected, its length is equal to that of its projection on the plane; for the line and its projection, being both terminated at two points perpendicular at the plane of projection, are parallel to each other, and comprised between parallels. In this particular case, therefore, the projection being given, the length of the right line, which is equal to it, is also given.

"A right line is always parallel to one of the two planes of projection, when its projection upon the second is parallel to the first of its planes.

"If the right line be at the same time oblique upon two planes, its length will be greater than that of either of its projections; but the true length may be obtained by a very simple operation.

"*Figure* 2.—Let A B be the right line; $a\ b$, $a'\ b'$, its given projections: to find its true length. From one of the extremities of the right line A, in the vertical plane falling from it, imagine a horizontal line, A E, stretching out till it meet in E the vertical line falling from the other extremity at B; this will give the rectangular triangle, A E B, which must be constructed in order to obtain the length of the right line A B, which is its hypothenuse. In this triangle, independently of the right angle, we know the side A E, which is equal to the given projection, $a\ b$. And if, in the vertical plane, we draw from the point a', the horizontal line $a'\ e'$, which is the projection of A E, it will cut the vertical line b' D at the point e, which will be the projection of the point E. Thus $b'\ e$ will be the vertical projection of B E, and consequently of an equal length with it. Having ascertained, by these means, the two sides of the triangle, it will be easy to construct the triangle, whose hypothenuse will give the length of A B.

"*Figure* 2.—being drawn in perspective, has no affinity to constructions done in the manner of projections. We shall here give the construction of this first question in all its simplicity.

"*Figure* 3.—The right line L M being supposed to be the intersection of the two planes of projection, and the lines $a\ b$, $a''\ b''$, the given projections of a right line; to find the length of this line. Draw through the point a'', the indefinite horizontal H e, which will cut the line $b\ b''$, at the point e, and upon it measure the length of $a\ b$, from e to H. Draw the hypothenuse H b'', and its length will be that of the right line required.

"As both the planes of projection are rectangular, this operation, which is performed upon one of the planes, may be also done upon the other, and will yield a similar result.

"From what has been said, the reader will perceive, that whenever we have the two projections of a body, terminated by plane surfaces, by rectilinear angles, and by the apices of

solid angles (projections which are reducible to the system of rectilinear angles) it will be easy to ascertain the length of any of its dimensions: for this dimension will either be parallel to one of the two planes of projection, or it will be at the same moment oblique to them both. In the first case, the required length of the dimension will be equal to its projection; in the second, it may be reduced from the two projections, by the method just described.

"We come now to describe the mode by which the projections of solids, terminated by planes and rectilinear angles are constructed; though there is no general rule for this operation: indeed, the construction of these projections will be more or less easy, according to the method in which the position of the apices of the angles of the solid is defined; the nature of the operation being governed by that of the definition. The case is precisely here as in algebra, in which there is no general method of reducing a problem to equations. In every particular instance, the process depends on the mode in which the relation between the given quantities and those sought for, is expressed: and it is only by a variety of examples that young students can learn how to lay hold of these affinities, and to express them in equations. So likewise, in descriptive geometry, it is only by a multitude of examples, and by the use of the rule and compasses in our schools, that we can acquire the habit of forming constructions, or accustom ourselves to make choice of the most familiar and elegant methods in each particular case. We may farther observe, that, as in analyses, when a problem is reduced to equations, there are methods of treating those equations, and of deducting from them the value of each unknown quantity; so also, in descriptive geometry, when the projections are made, there are certain general methods of constructing whatever may result from the terms, and respective positions of bodies.

"Nor is this comparison between descriptive geometry and algebra altogether useless: for these sciences are intimately connected. There is no construction of descriptive geometry, but what may be reduced to an analysis; and when questions require no more than three unknown quantities, each analysis may be looked upon as the record of a spectacle in geometry.

"It is much to be wished, that these two sciences were studied together: descriptive geometry would carry that evidence which is its peculiar characteristic, into the most complicated analytical operations; while on the other hand algebraical analyses would give to geometry, that generality which it stands in need of.

"The principle upon which we ground the theory of projections is convenient for describing the position of a point in space or that of an indefinite or terminated right line, and, consequently, for representing the form and position of a body terminated either with plain faces, rectilinear arrêtes, or the apices of solid angles; for when once we are acquainted with the position of all its arrêtes and of the apices of all its angles, the body itself is entirely known. But were all bodies bounded, either by an uniformly curved surface, all whose points were governed by the same law, as in spheres, or by an unconnected assemblage of several parts of differently curved surfaces, as in a body turned on a lathe; this principle would not only be inconvenient, impracticable, and destitute of the advantage of forming an idea of the shape, but would also be insufficient through want of variety.

"For instance: it is easy to perceive that this principle by itself, would be inconvenient and impracticable, if we wished to describe all the points of a curved surface; because it would be necessary not only to indicate each of them, as well by its horizontal, as its vertical projection, but also to have the two projections of the same point united together, in order to avoid a combination of the horizontal projection of one point with the vertical projection of another; and the most ready mode of thus uniting these projections, being to join them by one perpendicular right line to the line of intersection of the two planes of projection, the draught would become surcharged with a prodigious number of lines, and cause a confusion, which would increase in proportion as we would aim at accuracy and precision.

"We shall now prove this method to be insufficient, and destitute of the requisite copiousness.

"Amongst the vast variety of differently-curved surfaces, there are some which extend only through a finite and circumscribed portion of space, and whose projections are limited, as to extent, in every direction; as in the case of a sphere, the extent of whose projection on a plane is reduced to that of a circle, having its circumference equal to that of the sphere; and we must allow the plane, on which the projection falls, to be of dimensions sufficient to receive it. But all cylindric surfaces are as indefinite in a certain direction, as the right line by which they are generated; and the plane itself, the most simple of all surfaces, is indefinite in two ways. There are likewise a great number of surfaces, whose protuberant particles (*nappes*) shoot at once into all the regions of space. Now, as the planes on which projections are received, are unavoidably of a limited extent, this mode of describing the nature of a curved surface, had we no other than that of the two projections of each of the points by which it passes, could be only applicable to those of which the points of the surface correspond to the size of the planes of projection; all beyond this, could neither be expressed nor known: consequently, this mode would be insufficient. Lastly, it would want variety, because we could not deduce from it anything relative either to tangent planes to the surface, nor to its normals, nor to its two curvatures in each point, nor to its lines of inflection, nor to its returning arrêtes, nor to its multiplied lines and points, nor, in a word, to any of the affections necessary to be considered in operating on a curved surface.

"It is therefore necessary, that we should have recourse to some new principle, not only compatible with the former, but also capable of supplying its place, whenever it becomes in itself insufficient for our purpose. It is this new principle that we are now about to lay down.

"Every curved surface may be considered as generated by the movement of a curved line, either inflexible in form when its position is changed, or variable both in form and situation. As the universality of this proposition may render it difficult of comprehension, we shall explain it by some familiar examples.

"Cylindric surfaces may be generated in two principal ways, viz., either by the movement of a right line, which keeps constantly parallel to a given line whilst in motion, yet inclining always towards a given curve; or by the movement of the curve itself, taken in the foregoing instance as the conductor, which so moves, as that while from one point it inclines towards a given line, all its other points may describe parallels to this line. In both these modes of origin, the generating line, which is a right line in the first case, and a curve, of whatever description, in the second, invariably retains its form; only changing its position in space.

"Conical surfaces have, in like manner, two principal modes of being generated. First, they may be considered as generated by an indefinite right line, which being forced to pass always upon a given point, moves so as to lean constantly towards a given curve, that directs its movement. The only point through which it always passes the right line, is the centre of the surface, improperly called its *apex* or *head*. In

this mode, the generating line still preserves its identity, never ceasing to be a right line.

"Conic surfaces may also be generated in another way, which, for greater plainness, we shall here apply only to those with circular bases. The surfaces may be considered as bounded by the circumference of a circle, moving with its plane always parallel to itself, and its centre upon a right line passing through the apex; its radius being, in every movement, proportionate to the distance of the centre from the apex. Here it is evident, that if in its motion, the plane of the circle tends towards the apex of the surface, the radius of the circle will decrease, till, in passing the apex, it will be an absolute nullity, after which it will again increase indefinitely, in proportion as the plane, having passed the apex, is withdrawn farther and farther from it. In this second mode of generating, the circumference of the circle, which is the generating curve, not only changes its position, but its form also, at every motion; for, changing its radius, it consequently varies both in curvature and extent.

"Let us take a third example.

"A circular surface may be generated by the movement of a plane curve, turning about a right line; drawn in any direction upon its plane. In this way, we find the generating curve inflexible in form, but changeable in position. We may also see it generated by the circumference of a circle, moving with its centre always on the axis, and its plane being perpendicular to this axis, the radius will be uniformly equal to the distance of the point in which the plane of the circle cuts the axis, from that in which it cuts a given curve in space. Here the generating curve changes both in form and position.

"From these three examples, we may perceive that all curved surfaces may be generated by the movement of certain curved lines, and that there are none of which the form and position may not be accurately described from an exact and complete definition of its generation. This new principle forms a complement to the method of projections; and in proceeding, we shall have frequent occasion to be convinced of its simplicity and copiousness.

"It is not, therefore, by merely giving the projections of individual points, through which a curved surface passes, that we are enabled to determine its form and position; but by being able to construct for any point the generating curve, according to the form and position it would have in passing such point. And here we may remark, 1. That as every curved surface may be generated in an infinite number of different ways, it must depend upon the dexterity and knowledge of the operator, to make choice, among all the possible generations, of such as will require the most simple curve, and least complex considerations. 2. That long experience has taught us, instead of considering only one generating principle of a curved surface, as prescribed by the laws of motion and of the change of form in its generation, it is frequently more simple to take two generating principles, and to indicate for each point the construction of the two generating curves.

"Thus, in descriptive geometry, in order to express the form and position of a curved surface, it is only necessary, for any point of such surface, of which the projections may be taken at pleasure, to give the manner of constructing the horizontal and vertical projections of two different generators, which pass that point.

"We shall now proceed to apply these general principles to the plane, of all surfaces the most simple, and the most frequently in use.

"A plane is generated from the motion of a given right line, of a known position, which moves so that all its points may describe lines parallel to a second given right line. If this second line be itself in the plane in question, it may be also said that the plane is generated by such second right line moving so that all its points may describe lines parallel to the first.

"We have therefore an idea of the position of a plane, from an observation of the two right lines, each of which may be considered as its generator. The position of these two right lines in the plane which they generate, is altogether indifferent; it is only necessary, therefore, for projections, to make choice of such as are of the most simple construction. Hence, in descriptive geometry, the position of a plane is indicated by giving the two right lines along which it cuts the planes of projection. It is easy to recollect that these two right lines must meet the intersection of the two planes of projection in one and the same point, and that, consequently this must be the point, in which they meet themselves.

"As we shall have frequent occasion to bring planes under our consideration, we shall, for the sake of brevity, adopt the term *traces* to describe those right lines, by which they cut the planes of projection, and by which their position is indicated.

"Having settled these preliminaries, we now proceed to the solution of various questions, which will at once serve as exercises on the method of projections, and facilitate our farther progress in descriptive geometry.

"*First Question.—Figure* 4. A point, whose projections are D, *d*, and a right line, whose projections are A B and *a b*, being given; to construct the projections of a second right line, drawn from the point given, parallel to the first.

"*Solution.*—The two horizontal projections of the given right line, and of the line sought, must be parallel to each other; being the intersections of two vertical planes, parallel to a common plane. It is also the same with the vertical projections of similar right lines. Therefore, as the right line sought for must necessarily pass through the given point, its projections must also pass through those of the point respectively. If, then, from the point D, E F be drawn parallel to A B, and if from the point *d*, *e f* be drawn parallel to *a b*, the lines E F and *e f* will be the projections required.

"*Second Question.—Figure* 5. A plane whose two traces are A B, B C, and a point, whose projections are G, *g*, being given; to construct the traces of a second plane, drawn from the given point, parallel to the first.

"*Solution.*—The traces of the plane sought for, must be parallel to the respective traces of the given plane, because these traces taken in pairs, are the intersections of two planes parallel to a common plane. We have, therefore, only to find, for each of them, one of the points through which they respectively pass. To obtain this, from the given point, conceive a horizontal right line in the plane sought for; this line will be parallel to the trace A D, cutting the vertical plane in a point, which will be one of those of the trace of the plane sought for on it; and we shall have its two projections, by drawing the indefinite horizontal *g* F from the point *g*, and the right line G I from the point G, parallel to A B. If G I be produced to meet the intersection, L M, of the two planes of projection in the point I, such point will be the horizontal projection of the intersection of the horizontal right line with the vertical plane. This point of intersection, therefore, will be found upon the vertical line I F, drawn from the point I. But as it must also be found upon *g* F, it will be discovered at the point F, of intersection of the two latter right lines. Lastly, by drawing a line from F parallel to B C, we shall have upon the vertical plane the trace of the plane required; and if this trace be produced till it meet L M in the point E, and E D be drawn parallel to A B we

shall have the trace of the same plane upon the horizontal plane.

"If, instead of a horizontal right line in the plane sought for, a line parallel to the vertical plane were conceived, the construction following, by parity of reasoning, would be obtained:

"Draw from the point G, parallel to L M, the indefinite right line G D; from the point g, draw g H parallel to C B, producing it till it cut L M in the point H, whence draw H D perpendicular to L M: this latter will cut G D in D, whence if a parallel be drawn to A B, one of the traces of the plane sought for will be obtained; and if, having produced this trace to meet L M in E, E F be drawn parallel to B C, we shall have the trace on the vertical plane.

"*Third Question.—Figure* 6. A plane whose two traces are A B and B C, and a point whose two projections are D, d, being given; to construct, 1, the projections of the right line falling perpendicularly from the point upon the plane; 2, the projection of the point of coincidence of the right line with the plane.

"*Solution.* The perpendiculars D G, dg, falling from the points D and d upon the respective traces of the plane, will be the indefinite projections of the right line required: for if, along the perpendicular, a vertical plane be conceived, such plane will cut both the horizontal and the given planes, in two right lines, both of them perpendicular to the common intersection, A B, of the two planes; now, the first of these lines, being the projection of the vertical plane, is also that of the perpendicular which is included; therefore the projection of this perpendicular must pass through the point D, and the perpendicular to A B.

"The same demonstration will serve for the vertical projection.

"As to the point of coincidence of the perpendicular with the plane, it is evident that it must be found at the intersection of this plane, with the vertical plane drawn along the perpendicular; such intersection being projected indefinitely upon E F. By obtaining the vertical projection, fe, of this intersection, we shall find it to contain that of the point required; and as this point must be projected upon the right line dg, it will be found at the intersection, g, of the lines fe and dg. It remains, therefore, only to discover the right line fe: now, the intersection of the given plane with the vertical plane, which are perpendicular to each other, will meet the horizontal plane in the point E, whose vertical projection, e, will be found by dropping E e perpendicularly upon L M; and it will meet the vertical plane of projection in a point, whose horizontal projection is the intersection of the line L M with D G, produced, if necessary, and whose vertical projection must be at once upon the vertical line F f and the trace C B; of course, it will be at the point, f, of their intersection.

"The vertical projection, g, of the foot of the perpendicular being found, the construction of its horizontal projection will be easy; for by dropping the indefinite perpendicular g G upon L M, a right line will be obtained, which will contain the point required: and as the line D F must also contain it, it will be found at the point, G, of intersection of these two right lines.

"*Fourth Question.—Figure* 7. A right line whose two projections are A B, $a\,b$, and a point whose two projections are D, d, being given; to construct the traces of a plane drawn from the point, perpendicularly to the right line.

"*Solution.* We have seen from the preceding question, that the two traces must be perpendicular to the respective projections of the two right lines: it remains to be discovered what points each of them ought to pass through. For this purpose, let an horizontal line from the given point be conceived in the plane required, produced so as to meet the vertical plane of projection, and we shall find its vertical projection, by drawing the indefinite horizontal d G through the point d, and its horizontal projection by drawing a perpendicular to A B, through the point D, produced till it cut L M in H, which will be the horizontal projection of the point of coincidence of the horizontal with the vertical plane of projection. This point of coincidence, which must be found in the vertical line H G, and the horizontal line d G, and consequently at the point, G, of the intersection of these two lines, will be one of the points of the trace on the vertical plane; we shall then find this trace by drawing the line F C, from the point G, perpendicular to $a\,b$; and if from the point C, where the first trace meets L M, C E be drawn perpendicular to A B, we shall have the second trace required.

"The same process would discover the point of coincidence of the plane with the right line.

"Were it necessary to drop a perpendicular from the given point upon the right line, we should construct, as has just been described, the coincidence of the right line with the plane drawn by the given point, and which would be perpendicular to it; and we should obtain, from each of the two projections of the required perpendicular, two points through which it must pass.

"*Fifth Question.—Figure* 8. Two planes being given in position, by means of their traces A B and A b for one, and C D and C d for the other; to construct the projections of the right line upon which they intersect each other.

"*Solution.* All the points of the trace A B being found in the first of the two given planes, and all those of the trace C D being found in the second, the point E, of intersection of these two traces is evidently in the two planes, and is consequently one of the points of the required right line. In like manner, the point, F, of intersection of the two traces upon the vertical plane, is also another point of this right line. The intersection of the two planes is therefore so placed as to meet the horizontal plane in E, and the vertical plane in F.

"If, therefore, the point F be projected on the horizontal plane, which may be performed by dropping the perpendicular F f on L M, and if the line f E be drawn, it will be the horizontal projection of the intersection of the two planes. So, if the point E be projected on the vertical plane, by dropping the perpendicular E e on L M, and if the right line e F be drawn, it will be the vertical projection of the same intersection.

"*Sixth Question.—Figure* 9. Two planes being given, by means of the traces A B and A b for the first, and C D and C d for the second; to construct the angles formed by them.

"*Solution.* Having constructed, as in the preceding question, the horizontal projection, E f, of the intersection of the two planes; by conceiving a third plane perpendicular to them, and consequently perpendicular to their common intersection; this third plane will cut the two given planes in two right lines, containing between them an angle equal to the one required.

"The horizontal trace of this third plane will be perpendicular to the projection, E f, of the intersection of the two given planes, forming with the other right lines a triangle, of which the angle opposed to the horizontal side will be the one required. It remains, therefore, only to construct this triangle.

"It is quite indifferent through what point of the intersection of the two first planes the third passes; and we are at liberty to mark its trace upon the horizontal plane, at pleasure; provided that it be perpendicular to E f. Suppose

then, the line G H be drawn perpendicular to E *f*, terminating, in G and H, at the traces of the two given planes, and meeting E *f*, in the point I; this line will be the base of the triangle intended to be constructed. In fact, let us suppose that the plane of this triangle turns on its base, G H, as on a hinge, to adapt itself to the horizontal plane; in this motion, its apex, which was in the first instance placed on the intersection of the two planes, continues in the vertical plane drawn through such intersection, because the vertical plane is perpendicular to G H; and when the plane of the triangle is laid down, this apex will be found on one of the points of the line E *f*. It therefore remains only to discover the heights of the triangle, or the extent of the perpendicular dropped from the point I, on the intersection of the two planes.

"But this perpendicular is comprised in the vertical plane drawn from E to *f*; if, therefore, we conceive this plane to revolve about the vertical line *f* F, in order to apply itself to the vertical plane of projection; and if we carry *f* E from *f* to *e*, *f* I from *f* to *i*, the line *e* F will be the extent of the portion of the intersection comprised between the two planes of projection; and if from the point *i*, the perpendicular *i k* be dropped upon this line, it will give the height of the required triangle.

"Hence, by carrying *i h* from I to K, and completing the triangle G K H, the angle in K will be equal to the angle formed by the two planes.

"*Seventh Question.—Figure* 10. Two right lines intersecting each other in space, being given by their horizontal projections A B, A C, and by their vertical projections *a b*, *a c*; to construct the angle formed between them.

"Before we enter on the solution of this question, we may remark, that as the two given right lines are supposed to intersect each other, the point, A, of the coincidence of their horizontal projections, and the point, *a*, of the coincidence of their vertical projections, will be the projections of the point in which they cross each other, and will, consequently, be in the same right line, *a* G A, perpendicular to L M. Were the two points A and *a* not in the same perpendicular to L M, he given right lines would not intersect each other, and of course would not be in the same plane.

"*Solution.* Conceive the two given right lines to be produced so as to meet the horizontal plane, each in a point, and then construct these two points of coincidence. To perform this, produce the lines *a b* and *a c*, till they cut L M in the points *d* and *e*, which will be the vertical projections of these two points of coincidence. From the points *d* and *e*, draw upon the horizontal plane, and perpendicularly to L M, two indefinite right lines, *d* E and *e* E, which, as they must pass through one of these points, will determine their positions by their intersections, D and E, with the respective horizontal projections A B and A C, produced if necessary.

"This done, draw the right line D E, which, with the two parts of the given lines comprised between their intersecting point and the points D and E, will form a triangle, of which the angle opposite to D E will be the angle required: we have, therefore, only to construct this triangle. To do so, having dropped from the point A, the indefinite perpendicular A F, upon D E, conceive the plane of the triangle to turn as upon a hinge on its base D E, till it lie flat on the horizontal plane; the apex of this triangle, during its movement, will not depart from the vertical plane described by A F, and will at length apply itself in some degree upon the prolongation of F A in a point, H, of which it remains only to find the distance from the base D E.

"Now the horizontal projection of this distance is the right line A F, and the vertical height of one of its extremities above that of the other is equal to *a* G; hence, according to the property of *Figure* 3, if upon L M, A F be measured from G to *f*, and if the hypothenuse *a f*, be drawn, such hypothenuse will be the distance required. Finally, if *a f* be carried from F to H, and if from the point H the two lines H D and H E be drawn, the triangle will be complete, and E H E will be the angle sought for.

"*Eighth Question.*—The projections of a right line, and the traces of a plane, being given; to construct the angle formed by such line and plane.

"*Solution.* Suppose a line perpendicular to the given plane to be drawn from a certain point in the given right line, the angle formed by such perpendicular with the given right line, would be the complement of the required angle, the construction of which will resolve the question.

"Now, if upon the two projections of the right line, two points be taken, in the same perpendicular with the intersection of the two planes of projection; and if lines be drawn from these two points, perpendicular to the respective traces of the given plane, they will describe the horizontal and vertical projections of the second right line. The question will therefore be reduced to the construction of the angle formed by two right lines which cut each other, and will be of the same nature with the former.

"It is usual, in projecting a chart of a country, to imagine the remarkable points to be connected by means of right lines forming triangles, which are to be transferred to the chart on a smaller scale, but placed in the same relative order as those they represent. The operations necessary to be made on the earth consist chiefly of the measurement of angles, and of these triangles; and in order to the angles being described correctly on the chart, they ought each to be in a horizontal plane, parallel to that of the chart. If the plane of the angle be oblique to the horizon, it must not be represented, but its horizontal projection must be taken, which may always be found, if after measuring the angle itself, those angles which its two sides form with the horizon be also measured. Hence we derive the following operation, known under the appellation of *the reduction of an angle to the horizon.*

"*Ninth Question.*—The angle formed by two right lines, and the angles formed by such lines with the horizontal planes, being given; to construct the horizontal projection of the first of these angles.

"*Solution.—Figure* 11. Let A be the horizontal projection of the apex of the angle sought for, and A B that of one of its sides, so that the other side may be represented by A E. Conceive the vertical plane of projection to pass along A B; and having drawn the vertical indefinite line A *a*, through the point A, any point, as *d*, may be taken at pleasure, as the vertical projection of the apex of the angle observed. If from the point *d*, the right line *d* B be drawn, so as to make with the horizontal line, an angle *d* B A, equal to that made by the first side with the horizon, the point B will be the coincidence of this side with the horizontal plane. Also, if from the point *d*, the line *d* C be drawn, so as to make with the horizontal line an angle, *d* C A, equal to that made by the second side with the horizon; and if from the point A, as from a centre, with the radius A C, the indefinite arc of a circle, C E F, be described, the second side can meet the horizontal plane only in the points of the arc C E F. It remains, therefore, only to ascertain the distance between this point and some other, as B.

"Now this latter distance is in the plane of the angle observed. If, therefore, the right line *d* B be drawn, so as that the angle D *d* B may be equal to the angle observed, and

if d C be carried from d to D, the right line D B will be equal to such distance.

"Therefore, taking B as a centre, and, at an interval equal to C D, describing the arc of a circle, the point E, where it will cut the first, will be the point of coincidence of the second side with the horizontal plane; consequently, the right line A E will be the horizontal projection of such side, and the angle B A E that of the angle observed.

"The nine preceding questions barely convey an idea of the method of projections; they are inadequate to a display of all the resources: but in proportion as we rise to more general considerations, we shall take care to introduce such operations as will be most conducive to this object.

"*Of planes tangent to curved surfaces, and of normals.*

"There is no curved surface but what may be generated in several ways, by the movement of curved lines; therefore, if from any point of a surface, two generating lines be supposed to spring in the position they would naturally have in passing each other through such point, and if the tangents be supposed in this point, to each of the two generators, the plane described by such two tangents is *the tangent plane.* The point of the surface in which the two generators cut each other, and is at the same time common to the two tangents and to the tangent plane, is *the point of contact* between the surface and the plane.

"The right line drawn through the point of contact, perpendicularly to the tangent plane, is said to be *normal* to the surface. It is perpendicular to the ground of the surface, because the direction of such ground coincides, in every part, with that of the tangent plane, which may be considered as its prolongation.

"A knowledge of tangents and of normals to curved surfaces, is very useful in a great number of arts; in many, it is indispensable. We shall here adduce only a single example of each case, selected in architecture and painting.

"The several portions which compose vaults of hewn stone, are called *voussoirs*, and the faces on which two contiguous voussoirs touch each other. are denominated *joints*, whether the voussoirs form but a single course, or whether they be comprised in two successive courses.

"The position of the joints of vaults is subject to several conditions, which must necessarily be complied with, and which we shall demonstrate in succession, in the sequel of this discourse; but at present we must confine our attention to the object more immediately before us.

"One of the conditions required in the position of joints, is, that they be all perpendicular to each other, and to the surface of the vault. Any material deviation from this rule, not only destroys the general symmetry of the structure, but also diminishes the firmness and durability of the vault. For instance, if one of the joints be made oblique to the surface of the vault, one of the two continuous voussoirs will form an obtuse angle, and the other, an acute one; and in the reaction which these voussoirs would exert against each other, the two angles would present an unequal resistance, whence, in consequence of the fragility of the materials, the acute angle would bilge, and spoil the shape of the vault, as well as endanger the edifice. The reduction of vaults into voussoirs, therefore, absolutely requires a knowledge of planes tangent and normals to the curved surface of the arch.

"Let us take another example, from an art, which, at first view, seems to require a much less rigid attention to this rule.

"Painting is generally considered as consisting of two parts. The one is, properly speaking, *the art;* its object is to excite in the spectator a determinate emotion, to create in him a given idea, or to place him in a situation the most favourable for receiving a certain impression; it supposes in the artist a great knowledge of philosophy; exacts, on his part, a most intimate acquaintance with the nature of things, the mode in which they affect us, and the movements, even involuntary, by which such affection manifests itself. This can only be the result of a very refined education, such as no one receives, and such as we are far from giving to young artists: it is governed by no general rule, but is subject solely to genius.

"The other part of painting may be properly called *the trade:* its object is a correct execution of the conceptions of the former. Here nothing is arbitrary; all is foreseen, by the help of sound reasoning, as the necessary result of determinate subjects and given circumstances. When the form and position of an object are ascertained; when its nature, and the number and positions of all the bodies by which it may be illumined, whether by direct light or reflected rays, are understood; when the position of the eye of the spectator is determined; and when, in a word, every circumstance that can influence the vision, is well established and known, the tint of each of the points of the visible surface is absolutely determined. Whatever relates to the colour of this tint, or its brightness, depends on the position of the plane tangent in this point, with respect to the illuminating bodies and to the eye of the spectator. This may be discovered by mere reasoning, and when so determined should be applied with accuracy. Every diminution, or exaggeration, will change the appearances, alter the forms, and produce an effect quite different from that intended by the artist.

"I am aware that the rapidity of execution, which is often necessary, rarely admits of the use of a method which deprives the genius of all corporeal succours, and leaves it to the exercise of its faculties alone, as well as that it is much more easy for the painter to look at objects, to observe their tints, and to imitate them: but were he accustomed to consider the positions of tangent planes, and the two curvatures of surfaces in each of their points (curvatures which will form the subject of subsequent lessons) he would not fail to derive from this material method, a more advantageous result: it would enable him to supply effects which the omission of some circumstances had prevented him from producing, and to suppress others which had arisen from extraneous incidents.

"In conclusion, we may remark, that the vague expressions, such as *flats*, which painters are in the constant habit of using, are standing evidences of the need in which they are of more accurate knowledge, and of deeper reflection.

"Besides its utility in the arts, the knowledge of planes tangent and normals to curved surfaces, is one of the most fertile methods employed in descriptive geometry for the solution of questions, which it would be very difficult to resolve by any other process, as will appear from the following examples.

"The general mode of determining the plane tangent to a curved surface, consists, as we have already remarked, in conceiving at the point of contact, the tangents with two different generating curves, which would pass through this point, and in constructing the plane that would pass through these two right lines. In some particular cases, in order to shorten the construction, the strict letter of this mode is departed from, but an equivalent is always adopted.

"As to the construction of the normal, we shall not dwell upon it particularly, as it reduces itself merely to that of a right line perpendicular to the tangent plane, which is sufficiently understood.

"*First Question.*—From a supposed point on a cylindric

surface, of which the horizontal projection is given, to draw a tangent plane to that surface.

"*Solution.—Figure* 12. Let A B, *a b*, represent the horizontal and vertical projections of the given right line, to which the generator of the cylindric surface must be parallel; let E P D be the given curve in the horizontal plane, on which the generator must constantly rest, and which may be considered as the outline of the cylindric surface; lastly, let C be the given horizontal projection of the point supposed on the cylindric surface, from which the tangent plane must be drawn.

"Next, from the supposed point on the surface, whose horizontal projection is in C, imagine the generating right line in the position it would have, if it passed through that point: this generator being a straight line, will be its own tangent, and consequently one of the two right lines by which the position of the tangent plane will be determined; also, it will be parallel to the given right line: its two projections, therefore, will be respectively parallel to A B and *a b:* then, if from the point C, an indefinite line be drawn, parallel to A B, as E F, we shall have the horizontal projection of the generator. To obtain its vertical projection, we must suppose the generator to be produced upon the cylindric surface, till it meet the horizontal plane, which it can only do in a point, that will be at once on the projection E F, and on the curve E P D, and consequently the intersection of these two lines: thus the point will be determined by producing E F till it cut some part of the curve E P D.

"Two cases here present themselves: either the line E F will cut the outline of the cylinder in a single point, or it will cut it in several points. In examining these two cases separately, we shall suppose, in the first instance, that to whatever length the line E F may be produced, it shall cut the curve E P D only in the single point D.

"The point D being the trace of the generator, if it be projected on the vertical plane, by means of the perpendicular D *d*, and if from the point *d*, the line *d f* be drawn parallel to *a b*, we shall obtain the vertical projection of the generator. We are thus in possession of the two projections of one of the right lines, through which the required tangent plane must pass. The vertical projection of the point of contact ought to be on the line C c', drawn from the given point C, perpendicularly to L M; it should also be on *d f;* consequently it will be in the intersecting point, *c*, of those two lines.

"If the line E F cut the trace, E P D, of the cylindric surface in several points, as D and E, we must proceed for each in the same manner as that just directed for the point D, considered by itself, and we shall obtain the vertical projections, *d f, e f*, of as many generating lines, and the vertical projections, *c* c', of as many points of contact, as there are points of intersection between the line E F and the trace E P D.

"In the instance of *Figure* 12, the trace of the cylindric surface in the circumference of a circle, which has the property of being cut by a right line in two points; so that the vertical line elevated from the given point C, must meet the surface twice; first, in a point whose vertical projection is *c*, through which the generator passes when it touches upon the point D; and, secondly, in another point, whose vertical projection is c', through which the generator passes when it rests on the point E of the trace. These two points, although they have the same horizontal projection, are nevertheless very distinct, and should each have a particular correspondent tangent plane. Indeed, for each of the two points of contact, we must find the second right line, by which the position of the tangent plane is to be determined. Were we strictly to follow the general method, by considering the trace as a second generating line, it would be necessary to conceive it as passing successively through each of the points of contact, and to construct a tangent for each of such points; but in the present case of cylindric surfaces, a much more simple process may be pursued. For example: the plane tangent to the point C, *c*, touches the surface, throughout its extent, of the generating right line which passes from this point; it touches it, then, in D, which is a point of such generating line, and ought therefore to pass through the tangent to the trace at the point D. By parity of reasoning, we shall find that the plane tangent, C, c', ought to pass along the tangent to the trace in E. Therefore, if from the two points D, E, we draw the trace of the two tangent planes D K, E G, produced till they cut the line L M in two points K, G, we shall have, in the horizontal plane, the traces of the two tangent planes.

"It only remains to discover the traces of the same planes on the vertical plane; and having already for one of these traces the point K, and for the other, the point G, we have only to determine a single point for each of them.

"With this view, operating for the first of the two tangent planes, imagine the point to be constructed, to be one in which a horizontal line drawn upon the plane through the point of contact, would meet the vertical plane; we shall have the horizontal projection of such line, by drawing from the point C, a line parallel to the trace D K, which may be produced till it meet the line L M in the point I; and we may obtain its vertical projection by drawing from the point *c* an indefinite horizontal line. The point of coincidence of the vertical plane with the horizontal, will be found at once both upon the vertical line I *i* and the horizontal line *c i*, and will be at the point, *i*, of their intersection; therefore, if through the points *i* and K a line be drawn, it will give the trace of the first plane tangent to the vertical plane. By a similar process for the second tangent plane, we shall find its trace on the vertical plane, by drawing from the point C a line, C H, parallel to the horizontal trace E G, which may be produced till it cut L M in the point H, upon which the vertical line H *h* may be raised; from the point c' draw a horizontal line to cut the vertical line H *h*, in the point *h*, from which, and from the point G, by drawing the line G *h*, we shall obtain the trace required.

"*Second Question.*—From an imaginary point of a conic surface, of which the horizontal projection is given, to draw a tangent plane to such surface.

"The solution of this question differs only from the preceding, in having the generating right line, instead of being always parallel to itself, passing constantly from the apex whose two projections are given. We think it unnecessary to enlarge in this place, and leave the reader to examine for himself, with the assistance of *Figure* 13, should he stand in need of such aid.

"*Third Question.*—From an imaginary point of a surface revolving upon a vertical axis, and given in the horizontal projection, to draw a plane tangent to such surface.

"*Solution.—Figure* 14. Let A be the given horizontal projection of the axis, *a* a' its vertical projection, B C D E F the given generating curve, considered in a plane drawn from the axis, and G the given horizontal projection of the point of contact.

"If from the point of contact, and from the axis, a vertical plane be conceived, whose projection would be the indefinite horizontal line A G, such plane must cut the revolving surface in a curve, which will become the generator, passing through the point of contact: if from the point G, a vertical line be conceived, it will meet the generating curve, and consequently the surface, in one or several points, which will become so-

many points of contact, of which G will be the common horizontal projection. All these imaginary points of contact will be found in the plane of the generator, by carrying A G upon L M, from a to e, and drawing through the point e a line parallel to $a\,a'$; all the points, E, C, in which this line cuts the curve B C D E F, will be the intersections of the generating curve with the vertical line drawn through the point G, and will indicate the altitudes of as many points of contact above the horizontal plane. To obtain the vertical projections of these points of contact, draw through all the points, E, C, indefinite horizontal lines, which will contain such projections; and as they are also contained in the line perpendicular to L M, drawn from the point G, the intersections, $g\,g'$, of this line with the horizontal lines, will be the projections of the several points of contact.

"Now, if from each point of contact, a section be conceived, made by a horizontal plane, such section, which may be considered as a second generator, will be the circumference of a circle, whose centre will be in the axis, and of which the tangent, which must be perpendicular to the extremity of the radius, will also be perpendicular to the vertical plane drawn through A G, in which the radius is found: therefore the tangent plane which must pass through this tangent, will be also perpendicular to the same vertical plane, and will have, upon the horizontal plane, its trace perpendicular to A G. We only want, therefore, the trace of each of the tangent planes, to enable us to discover its distance from the point A: now, if through the points E, C, we draw to the first generator the tangents E I, C H, produced till they meet L M in the points I, H, the lines a I, a H, will be equal to those distances; therefore, if these lines be transferred from A to i, and from A to h, and if through the points i and h, the perpendiculars i Q, h P, be drawn to A G, and produced till they meet the line L M, we shall have, on the horizontal plane, the traces of all the tangent planes.

"To find on the vertical plane, the traces of the same planes, we must suppose for each point of contact, and in the correspondent tangent plane, a horizontal line produced to the vertical plane of projection; this line, which is the tangent to the circle, will determine, on this plane, which belongs to the trace. Now, for all the points of contact, these lines have the same horizontal projection, viz. the line G K drawn from the point G, perpendicularly to A G, and terminating in the right line L M. If, therefore, from the point K, an indefinite perpendicular, K $k\,k'$, be drawn upon L M, it will contain all the points of coincidence of the horizontal lines with the vertical plane of projection. But as these points of coincidence will also be found on the respective horizontal lines drawn through the points E, C; the intersections k, k', of such horizontal lines with the vertical line K, k', will be each a point of the trace of one of the tangent planes. Thus the line Q k will be on the vertical plane, the trace of one of the tangent planes; the line P k' will be that of another; and so of the rest, were there a greater number.

"We shall confine ourselves for the present, to the three preceding examples, because they are sufficient for all the surfaces, whose generation we have defined. In the course of this work, we shall have occasion to investigate the generations of tribes of surfaces, infinitely more numerous: and as they present themselves, we shall apply the same method to the determination of their tangent planes, and of their normals. At present we are about to propound a question, to the solution of which the consideration of the tangent plane may be appropriately and usefully applied.

"*Fourth Question.—Figure* 15. Two right lines being given, by their horizontal projections, A B, C D, and by their vertical projections, $a\,b$, $c\,d$; to construct the projections, P N, $p\,n$, of their shortest distance; that is to say, of the line that is at one and the same time perpendicular to both; and to find the quantity of this distance.

"*Solution.*—From the first of the two given right lines, conceive a plane parallel to the second; which is always possible, because if from any point whatever of the first, a line be drawn parallel to the second, and if this third line be conceived to move parallel to itself along the first, it will generate the plane spoken of. Imagine, also, a cylindric surface, with a circular base, having the second given right line for its axis, and the distance required for its radius; this surface will be touched by the plane in a line parallel to the axis, and will cut the first right line in a point. If from this point, a perpendicular to the plane be drawn, it will be the line required; for it will pass, in fact, through a point of the first given right line, and will be perpendicular to it, as it would to a plane passing along this right line; it will also intersect the second right line perpendicularly, because it will be a radius of the cylinder, of which such second line is the axis.

"It remains, then, only to construct, successively, all the parts of this solution.

"(1.) To construct the traces of the plane drawn through the first right line parallel to the second, we must first find the point, A, wherein this first line meets the horizontal plane, and which will be a point of the horizontal trace. To effect this, produce the vertical projection $b\,a$ till it cut the line L M in the point a, draw a A perpendicular to L M, and its intersection with the horizontal projection A B will determine the point A. Through the point in which the first right line cuts the vertical plane, whose projections are B b, conceive a right line parallel to the second given right line, and construct its projections by drawing, indefinitely, B E parallel to C D, and $b\,e$ parallel to $c\,d$. In like manner, construct the point, E, of coincidence of this parallel with the horizontal plane, by drawing e E perpendicular to L M; and the point E will be a second point of the horizontal trace of the plane. Then, if the right line A E be drawn, and produced till it cut, in the point F, the line L M, it will give the horizontal trace; and it is evident, that if through the points F and b, the right line F b be drawn, we shall have the trace on the vertical plane.

"(2.) To construct the line of contact of the plane with the cylindric surface; from any point of the second right line, which is the axis of the cylinder (as from the point C, for example, in which it meets the horizontal plane) drop a normal, that is, a perpendicular upon the tangent plane: and the foot of such normal will be a point of a line of contact.

"To find this foot, according the method already laid down in *Figure* 6, first construct the indefinite projections of the normal, by drawing through the point C, the line H G perpendicular to the trace A E, and through the point c, the line c K, perpendicular to the trace F b; then having produced H G till it meet A E in the point G, and L M in H, project the point G in g, and the point H in h, on the trace F b; draw the line $g\,h$, whose intersection with c K will determine the vertical projection, i, of the foot of the normal; and we shall have, on G H, the horizontal projection of the same point by letting I i fall perpendicularly on L M. The projections, i, I, of the foot of the normal being found, draw I N through the point I, parallel to C D, and $i\,n$, parallel to $c\,d$, and we shall have the projections of the line of contact of the plane with the cylindric surface. Lastly, the points N, n, in which these projections meet those of the first given right line, will be the projections of the point of such line, through which the common perpendicular required will pass.

"(3.) Having ascertained the projections, N, n, of one of the points of the required common perpendicular, it will be sufficient to obtain the projection of the perpendicular itself, to draw through the points N, n, the right lines N P, $n\ p$, perpendicular to the respective traces A E, F b; and the parts N P and $n\ p$ of these perpendiculars, comprised between the projections of the two given right lines, will be the projections of the required shortest distance.

"(4.) In conclusion, if the size of this shortest distance be desired to be known, it may be constructed by the process of *Figure* 3.

"The consideration of a cylindric surface touched by a plane, was not essential to the solution of the preceding question. After having supposed a plane parallel to the two given right lines, we might through each of these lines have drawn to such plane, a perpendicular plane; and the intersection of these two planes would have been the direction of the required shortest distance. We content ourselves with announcing this second method, and advise the reader to seek its construction by way of exercise.

"In the several questions which we have resolved relative to planes tangent to curved surfaces, we have always supposed the point, through which the tangent plane should be drawn, to be taken on the surface, and to be itself the point of contact: this condition alone sufficed to determine the position of the plane. But it is different when the point through which the plane should pass is taken out of the surface.

"In order to determine the situation of a plane, it must satisfy three several conditions, each equivalent to that of passing through a given point. Now, in general, the property of being tangent to a given curved surface, when the point of contact is not indicated, is only equivalent to one of these conditions: if, therefore, we propose to determine the position of a plane by conditions of this nature, we shall generally have occasion for three. For instance: suppose three curved surfaces to be given, and that a plane be tangent to one of them, in any point whatever; we can conceive that such plane would move around the surface, without ceasing to touch it: it would do so in every direction; only the point of contact would shift its situation on the surface, in proportion as the tangent plane changed its position; and the direction of the point of contact would be similar to that of the motion of the plane. Suppose this movement to be made in a certain direction till the plane meet the second surface, and touch it in a given point: then the plane would be tangent to the two first surfaces at once, and its position would not yet be fixed. Indeed, the plane may be supposed to turn about the two surfaces, without ceasing to touch them both. It will no longer, however, be free to move in every direction, as before, but will be confined to one only. In proportion as the plane changes its position, the two points of contact will move each upon the surface to which it belongs; so that if a right line be conceived as passing through those points, their movements will be in the same direction with respect to such line, when the plane touches the two surfaces on the same side, and they will be in a contrary direction, when it touches one surface on one side, and the other on the contrary side. Lastly, imagine this motion, which is the only one that can now take place, to be continued till the plane touch the third surface in a certain point; then its position will become fixed, and it can no longer move without ceasing to be tangent to one of the three surfaces.

"Hence we may perceive, that to determine the position of a plane by means of indeterminate contacts with given curved surfaces, we shall generally require three such surfaces. Thus, were it proposed to draw a tangent line to a given curved surface, this condition would be equivalent to only one of the three to which the plane is capable of answering: we might, again, take two others, at pleasure, and for example, make the plane pass through two given points, or, which is the same thing, along a given right line. Were it essential that the plane should be tangent to two surfaces at once, two conditions would be fulfilled; there would remain but one to be disposed of, and the plane could only be brought to pass through one given point.—Lastly, when the plane touches three given surfaces at once, there remains no longer any condition to be disposed of; its position is determined.

"The preceding observations relate to curved surfaces generally; yet we must except from them, whatever regards cylindric, conic, and developable surfaces; in which the contact with the plane is not reduced to a single point, but extends along the whole length of an indefinite line, which loses itself in the generator, in one of its positions. The property of a plane touching one only of these surfaces, would be equivalent to two conditions, since it would subject it to pass along a right line; and there would only remain one condition to be disposed of, viz., to make it pass through a given point. It were in vain, therefore, to propose to draw a plane, that should be at one time tangent to two of these surfaces, much less to three of them, unless there were some peculiar circumstances which should render these conditions compatible.

"It may not be altogether useless, before we proceed farther, to illustrate by a few examples, the necessity there is for drawing planes tangent to curved surfaces through points taken from the outside of them. The first of these examples is selected from the construction of fortifications.

"In treating of the general principles of fortification it is taken for granted, first, that, in every direction, the ground by which the place is surrounded, at least within the reach of cannon-shot, is flat, and free from every eminence that might be converted to advantage by a besieging army. This hypothesis being settled, the draught of the place is next determined, with its half-moons, covered ways, and advanced works; the bearings of the various parts of the fortifications upon each other are then marked out, so that they may all contribute, in the most efficacious manner, to their mutual and reciprocal defence. But, in order to apply these principles to cases where the surrounding country presents some height, of which besiegers might take advantage, and from which it is requisite that the fortification should be made to defile, a new consideration presents itself. If there be only a single eminence, two points should be fixed upon in the place, through which might be conceived a plane tangent to the height, from which it is desirable to defile: this tangent plane is denominated *the defiling plane;* and all the parts of the fortification must receive the same relief above such plane, as they would have had above the horizontal plane, had the country been quite level: by this means, they all acquire, relatively upon each other, and collectively upon the neighbouring height, a command equal to what they would otherwise have possessed over the flat country: and the fortification will possess the same advantages as in the first case. As to the choice of the two points, through which the defiling plane ought to pass, it must be conformable to the two following conditions: 1st, That the angle formed by the plane with the horizon, be the least possible, in order that, the platforms having less slope, the service of defence may be attended with fewer impediments; 2dly, That the relief of the fortification above the natural ground, be likewise as little as possible, that its construc-

tion may require less labour, and be attended with less expense.

"Should there be two heights in the environs of the place, from which the fortification should defile, the defiling plane must be tangent to the surfaces of both, at the same time: and to determine its position, there is but one disposable condition; and it is to be disposed of, by choosing in the place, a point, through which the plane may pass, as nearly conformable as possible to the conditions prescribed in the first case.

"The second example we shall take, is from painting.

"The surfaces of bodies, especially when polished, present brilliant points, whose lustre may be compared to that of the luminous body by which they are enlightened. The brightness of these points is greater, and their extent more confined, in proportion as the surfaces are more polished. When the surfaces are unpolished, the brilliant points have much less lustre, and occupy a greater portion of the surface.

"In every surface, the position of the bright point is determined by the following condition; that the incidental ray of light, and the reflected ray, directed to the eye of the spectator, be in the same plane, perpendicular to the plane tangent in this point, and make equal angles with it; for the shining point of the surface acts as a mirror, and reflects upon the eye a portion of the image of the luminous object. The determination of this point demands the utmost precision: for be the design never so correct, or the apparent contours traced with mathematical nicety, the least mistake committed in fixing the position of the brilliant point would be productive of the most palpable errors in the appearance of the shapes. We will give a single, but very striking case in proof.

"The surface of the ball of the eye is polished, and covered with a thin moisture, which renders the gloss more perfect. When we look upon an open eye, we see a bright point upon its surface, of great lustre, but of very limited extent, whose position depends upon the situation of the observer and the direction of the illuminating object. Were the surface of the eye perfectly spherical, it might turn on its vertical axis without in the least affecting the position of the brilliant point: but the surface being lengthened in the direction of the axis of vision, the position of the point is changed every time that the eye moves upon its vertical axis. Long experience having made us familiar with this change, our judgment, as to the direction of the eye, is considerably biassed by it. By the difference of position in the bright points upon the balls of the two eyes of a person, we chiefly judge whether he squint, or not; whether he look towards us; and when he does not, to which side his attention is directed.

"We do not pretend to infer from this example, that it is indispensable, in a picture, that the position of the brilliant point upon the ball of the eye be geometrically defined; our intention is merely to demonstrate how trifling errors as to this position may produce considerable distortion in the apparent form of the object, though in other respects the tracing of its apparent outline may remain the same.

"We now proceed to the determination of planes tangent to curved surfaces, drawn through points taken on the outside of them.

"The surface of the sphere is one of the most simple that can fall under our consideration; it has common generations with a great number of different surfaces; we may, for example, class it among revolving surfaces, and say nothing particular relative to it. But its regularity is productive of remarkable results, some of which are curious from their novelty, and with them, in the first instance, we are now about to be occupied, not so much on their own account, as to acquire, by the observation of the three dimensions, a habit, of which we shall stand in need, for more general and useful subjects.

"*First Question.*—Through a given right line to draw a tangent plane to the surface of a given sphere.

"*Solution.*—First method. *Figure* 16. Let A, a, be the two projections of the centre of the sphere; B C D, the projection of the great horizontal circle; E F, e f, the two indefinite projections of the given right line. Through the centre of the sphere, imagine a plane perpendicular to the right line, and construct, by the methods given under *Figure* 6, the projections G, g, of the point of coincidence of the right line with the plane.

"From this position, it is evident, that from the given right line two tangent planes may be drawn to the sphere, the first on one side, the second on the other, and, consequently, that the sphere will be placed between them: this indicates two different points of contact, whose projections we must now construct.

"If from the centre of the sphere, a perpendicular be conceived to fall upon both the tangent planes, they will each be bounded, at the point of contact with the surface of the sphere, by the corresponding planes; and will both be in the plane perpendicular to the given right line: therefore the two points of contact will be in the section of the sphere by the perpendicular plane; a section which must be the circumference of one of the great circles of the sphere, and to which the two sections made in the tangent planes by the same plane will be tangent.

"If in the perpendicular plane, and through the centre of the sphere, an horizontal line be imagined, whose vertical projection may be obtained by drawing the horizontal line a h, and its other projection by letting the perpendicular A H fall upon E F; and if the perpendicular plane be conceived to turn upon this horizontal line, like a hinge, till it become horizontal itself; it is evident that its section with the surface of the sphere would be lost in the circumference B C D, that the two points of contact would then be upon this circumference, and that were the point J constructed, in which, by this movement, the perpendicular plane would meet the given right line; the tangents J C, J D, drawn to the circle B C D, would determine these two points of contact to the position in which they then appear. It is easy to construct the point J, or, which is tantamount, to find its distance from the point H; for the horizontal projection of this distance is G H, and the difference of the vertical heights of its extremities is g g'; therefore by transferring the distance G H upon the horizontal line a h, from g to h, the hypothenuse h g will be the amount of this distance; and by transferring g h upon E F, from H to J, and drawing the two tangents J C, J D, the two points of contact, C, D, will be determined to the position they assumed, whilst the perpendicular plane was laid upon the horizontal one.

"Now, to find their projections in the position which they ought naturally to have, we must suppose the perpendicular plane to be restored to its original position, by turning it back upon the horizontal line, or hinge, A H, and it will carry with it the point J, the two tangents J C, J D, produced till they cut A H in the points K K', and the chord C D, which will likewise cut A H, in the point N. In this movement, it is evident, that the points K, K', N, which are upon the hinge, will be fixed, and that the two points of contact C, D, will describe arcs of circles, which will be in planes perpendicular to the hinge, and whose horizontal projections will be obtained by dropping from the points C D, the indefinite perpendiculars

C P, D Q, upon A H. The horizontal projections of the two points of contact will therefore be found upon the two right lines C P, D Q. But in the retrograde movement of the perpendicular plane, the two tangents J C K′, J K D do not cease to pass through the respective points of contact; and when this plane is returned to its primitive position, the point J is projected anew in G, and the two tangents are projected according to the right lines G K′, G K. The two latter, therefore, must each contain one of the points of contact; and, in fine. the intersections of these two right lines with the respective lines C P, D Q, will determine the horizontal projections, R, S, of the two points of contact, which are found in the same line with the point N.

"To obtain the vertical projections of the same points, first, draw the indefinite perpendiculars R *r*, S *s*, upon L M; then by projecting the points K K′, to *k*, *k′*, and drawing the lines *g k*, *g k′*, from the point *g*, we shall have the vertical projections of two similar tangents. These lines, therefore, will contain the projections of the respective points of contact; and the points, *r*, *s*, of their intersection with the vertical lines R *r*, S *s*, will be the projections required.

"The horizontal and vertical projections of the two points of contact being found, to construct, upon the horizontal plane the traces of the two tangent planes, lines parallel to the given right line must be conceived to pass through each of the points of contact. These lines will be in the respective tangent planes, and their horizontal and vertical projections will be obtained by drawing R U, S V, parallel to E F, and *r u*, *s v*, parallel to *e f*. On the horizontal plane, construct the trace, T, of the given right line, and the traces, U, V, of the two last lines; and the lines T U, T V, will be the traces of the two tangent planes.

"Instead of supposing fresh lines to pass through the points of contact, we may find the traces of the two tangents G R, G S, which will answer the same purpose. As to the traces of two similar planes with the vertical plane, they may be obtained by the method already so often alluded to.

"This solution may be rendered much more elegant by making the two planes of projection pass through the centre of the sphere itself. By this mode the two projections of the sphere would be mingled in the same circle, and the productions of the right lines would not be so long. We have only separated the two projections for the sake of perspicuity in the exposition: for it is easy to give to the construction all the conciseness of which it is susceptible.

"Second Method.—*Figure* 17. Let A, *a*, be the two projections of the centre of the sphere; A B, or *b*, its radius; B C D, the projection of its great horizontal circle; and E F, *e f*, the projections of the given right line. Conceive the plane of the great horizontal circle produced till it cut the given right line in a certain point, and we shall have the vertical projection of the plane, by drawing the indefinite horizontal line *b a g* through the point *a*; the point *g*, where this horizontal line cuts *e f*, will be the vertical projection of the point of coincidence of the plane with the given right line; and we shall have the horizontal projection, G, of this point by projecting *g* upon E F.

"This done, take the same point for an apex, and conceive a conic surface covering the sphere, all whose generating lines touch it in their respective points; now, we shall have the projections of the two horizontal generators of such conic surface, by drawing from the point G, the two lines G C, G D, tangent to the circle B C D, and which will touch it in the two points C, D, as may be easily determined. The conic surface will touch that of the sphere, whose line C D will be the diameter, whose plane will be perpendicular to the axis of the cone, and consequently vertical, and whose horizontal projection will be the line C D.

"If from the given right line two tangent planes to the conic surface be conceived, each of them will touch it, according to one of the generating lines, which will be at the same time on the conic surface and on the plane; and since such generating line also touches the surface of the sphere in one of its points on the circumference of the circle projected in C D, it follows, that this point is at once on the conic surface, on the plane which touches it, on the surface of the sphere, and on the circumference of the circle projected in C D, and that it is a point of contact common to all these objects. Hence we may conclude, 1st, That the two planes tangent to the conic surface, are also tangent to the surface of the sphere; 2dly, That their points of contact with the sphere, being in the circumference of the circle projected in C D, must be themselves projected on some part of this right line; 3dly, That the right line passing through the two points of contact, being comprised in the plane of the same circle, must also be projected indefinitely upon C D.

"We next proceed to an operation, for the plane of a large circle parallel to that of the vertical projection, similar to that which we have just finished for the great horizontal circle. The horizontal projection of such plane will be the right line B A H, indefinitely parallel to L M; the point wherein it meets the given right line will be horizontally projected to the intersection H, of the two right lines E F, B A H; and its vertical projection will be obtained by projecting the point H upon *e f*, in *h*. Conceive a new conic surface, whose apex shall be in this point of coincidence, and which, like the former, shall cover the sphere; and we shall have the vertical projections of the two extreme generating lines of such surface, by drawing from the point *h*, to the circle *b* K I, the tangents *h* K, *h* I, which shall touch it in such points, K I, as we may determine. This second conic surface will touch that of the sphere, in the circumference of a new circle, of which K I will be the diameter, and of which the plane, perpendicular to that of the vertical projection, will, consequently, be projected indefinitely upon K I. The circumference of this circle will likewise pass through the two points of contact of the sphere with the tangent planes required; whence the vertical projections of those two points of contact will be somewhere upon K I; and the right line by which these two points are united, will also be projected upon the same line K I.

"Thus the right line drawn through the two points of contact, is projected horizontally upon C D, and vertically upon K I; it meets the plane of the great horizontal circle in a point, whose vertical projection is at the intersection, *n*, of K I with *b a g*, and whose horizontal projection may be obtained by projecting the point *n* upon C D.

"This done, suppose the vertical plane of the circle, projected in C D, to turn upon its horizontal diameter, as upon a swivel, so as to become horizontal, and that it draw with it, in its movement, the two points of contact, through which its circumference passes, and the right line by which those two points are united. Construct this circle, in its new position, by describing upon C D, as a diameter, the circle C P D Q; and if the position assumed by the line uniting the two points of contact be constructed, it will cut the circumference C P D Q in two points, which will determine them upon this circumference considered in its horizontal position.

"The point, N, of the line of the two contacts, being upon the swivel C D, does not change its position by the movement: this line must, therefore, pass through such point when it has become horizontal. Besides, the point in which

it meets the plane of the great circle, parallel to the vertical projection (a point whose horizontal projection is in the coincidence, O, of the two lines C D, B A H, and whose vertical projection t, is found by projecting the point O upon K I) describes in its movement upon the swivel C D, a quarter of a circle perpendicular to C D, whose radius is the vertical line $o\ t$; if, then a line be drawn through the point O, perpendicular to C D, and if upon such perpendicular $o\ t$ be transferred, from O to T, the point T will be one of those of the line of contact, when it becomes horizontal. Therefore, if a line be drawn through the points N and T, its two points of coincidence, P, Q, with the circumference C P D Q, will be the two points of contact considered in the vertical plane, when laid down.

"To obtain the horizontal projections of the same two points in their natural positions, imagine the circle C D P Q to be returned to its original station, by turning on the same swivel C D. In this movement, the two points P, Q, will describe quarter-circles in the vertical planes perpendicular to C D, whose horizontal projections will be the perpendiculars P Q, R S, dropping upon C D. The horizontal projections of the two points of contact will then be respectively upon the lines P Q and R S; and as we have seen that they must likewise be upon C D, they must, consequently, be upon the two points of coincidence R and S.

"The vertical projections, r, s, of the same two points may be obtained, by projecting the points R and S upon K I; or, which amounts to the same, by transferring upon the vertical lines R r, S s, beginning from the horizontal line $b\ a\ g$, $r'\ r$, equal to P R, and $s'\ s$, equal to Q S.

"The horizontal and vertical projections of the two points of contact being constructed, the traces of the two tangent planes may be determined according to the method of the first solution.

"This second solution may be rendered much more concise, by making the planes of projection pass through the centre of the sphere; which would reduce the two projections to one figure.

"These latter considerations lead us to the discovery of some remarkable properties of the circle, of the sphere, of conic sections, and of curved surfaces of the second degree.

"It has been seen, that the two conic surfaces bounded by a sphere, would each touch it in the circumference of a circle, and that their circumferences would both pass through the two points of contact of the sphere with the tangent planes. This property is not peculiar to the two conic surfaces that we have considered, but applies to all such as have their apex in the given right line, and are circumscribed by the sphere. If, therefore, we suppose a prime conic surface, which, having its apex upon the given right line, is bounded by the sphere; and if this surface be supposed to move so as that its apex may run along the right line without ceasing to be contained within, and tangent to the sphere; it will in any of its positions touch the sphere in the circumference of a circle: all which circumferences will pass through the same two points in which the sphere comes in contact with the two tangent planes; and the planes of these circles will intersect each other upon one right line, which is that of the two contacts. If now the plane be conceived as drawn from the given right line, and from the centre of the sphere, it will pass through the axes of all the conic surfaces, will be perpendicular to the planes of all the circles of contact, consequently to the right line that is their common intersection, and cut all these planes in right lines that will pass through one point.

"By reciprocity, a sphere and a right line being given, if a number of planes, taken at pleasure, be conceived as passing along the right line, which shall cut the sphere, each in the direction of a circle; and if, for each of such circles, a right conic surface be conceived, of which it shall be the base, and which shall be confined within the sphere, the apices of all such conic surfaces will be another identical right line.

"By merely considering what happens in drawing the plane from the given right line, and from the centre of the sphere, we are led to the two following propositions, which are immediate corollaries of what has preceded.

"*Figures* 18 and 19.—Given in a plane, a circle, whose centre is A, and any right line whatever, as B C; if, after having drawn from a point, as D, of the right line, two tangents to the circle, and the lines E F connecting the points of contact, the point D be supposed to move along the right line B C, drawing with it the two tangents, without ceasing to touch the circle; the two points will shift their position, as well as the line E F, by which they are united, but the latter will always pass through the same point, N, upon the perpendicular, A G, dropped from the centre of the circle upon the right line B C.

"And, reciprocally, if, through a point, as N, taken in the plane of a circle, a number of lines, as E F, be drawn at pleasure, each cutting the circumference of the circle in two points; and if through these two points two tangents to the circle, E D, F D, be drawn, to meet in a point, as D, all the other points of intersection, found in the same manner, will be upon the same right line, B C, perpendicular to A N.

"It is not because all the points of the circumference are equally distant from the centre, that the circle possesses the property just described; but because it is a curve of the second order, and has all its conic sections of the same quality.

"*Figure* 20.—For example, let A E B F be a conic section of any kind, and C D any given right line upon its plane: suppose the curve to turn upon one of its axes, A B, to generate a surface of revolution, and imagine the two tangent planes to this surface drawn from the right line C D; the two planes will each have their particular point of contact. Now take for an apex, any point whatever, as H, of the right line C D, and conceive the conic surface contained within, and tangent to the revolving surface, and it will touch the latter in a curve that must necessarily pass through the same two points of contact as the tangent planes. This curve will be plain; its plane, which will be perpendicular to that of the given conic section, will be projected upon the latter, according to the line E F; and this line will pass through the points of contact of the tangents with the conic section, drawn from the point H. Now, suppose the apex, H, of the conic surface to move along the right line C D, without ceasing to be contained within, and tangent to the revolving surface; in any of its positions, its curve of contact will possess the same properties of passing through the two points of contact with the tangent planes, of being plain, and of having its plane perpendicular to the conic section. The planes, therefore, of all the curves of contact will touch the ends of the line that unites the two points of contact, which is itself perpendicular to the plane of the conic section, and hence the projections of all the planes will be right lines that must all touch the ends of the projection, N, of the line, by which the two points of contact are joined.

"This proposition is only a particular case of another more general one, that takes place in the three dimensions, and which we shall be content with announcing in this place.

"Any curved surface whatever, of the second degree, and

a conic surface contained within, and touching it, whose apex is a point chosen at pleasure, being given in space; if the conic surface move without ceasing to be contained within, and to touch the curved surface, but so as that its apex be kept in a right line, the plane of the curve of contact of the two surfaces will always pass upon one right line (which will be determined by the contacts of the surface of the second degree with the two tangent planes that pass along the line of the apices); and if the conic surface move so as that its apex be always in the same plane, the plane of the curve of contact will always pass upon the same point.

"*Second Question.*—From a given point, to draw a plane tangent to the surface of two given spheres.

"*Solution.—Figure* 21.—Let A, *a*, be the two projections of the centre of the first sphere; B, *b*, those of the second; and C, *c*, those of the given point. After having drawn the indefinite lines A B, *a b*, which are projections of the line that would pass through the two centres, and having constructed the projections G E F, *g e f*, H I K, *h i k*, of the great circles of the two spheres parallel to the planes of projection, conceive a conic surface containing the two spheres within it, and touching them both at the same time; the apex of this surface will be in the line which passes through the two centres. Then draw to the two circles G E F, H I K, the two common tangents E H, F K, meeting in the point D, of the right line A B; this point will be the horizontal projection of the apex of the cone, whose vertical projection, also, will be obtained by projecting the point D to *d*, on the production of *a b*. Lastly, draw the projections C D, *c d* of the right line passing through the apex of the cone and the given point. Now, if from this latter line two tangent planes be conceived to the conic surface, they will each touch it in one of its generating lines, and consequently will both be tangent, at the same time, to the two spheres. The question is therefore reduced to drawing two planes tangent to the surface of one of the spheres, from the right line that passes through the apex of the cone and the given point; which may be done as in the preceding question, and the two planes will also be tangent to the second sphere.

"It must here be remarked, that the same two spheres may be supposed to be contained within two conic surfaces. The first conic surface will envelope them both on the outside, and will have its apex on the outside of one of the spheres, with respect to the other, and the tangent planes to it will touch the two spheres on the same sides. The second conic surface will also envelope both spheres, but will have its apex between the two centres. The horizontal projection, D′, of this apex will be found by drawing to the circles E F G, H I K, the two interior tangents, which intersect each other in a point of the line A B; and its vertical projection by projecting the points D′ to *d′*, upon *a b*. The two tangent planes, drawn to this conic surface will also each touch the two spheres; but they will touch the first on one side, and the second on the other. Thus, four different planes may answer this question: for two of them, the two spheres are on the same side of the plane; and for the two others, they are on different sides.

"*Third Question.*—To draw a plane tangent at the same time to three spheres of given dimensions and positions.

"*Solution.*—Imagine the plane tangent at the same time to the three spheres; suppose, also, a conic surface containing the two first of those spheres, and touching them both; and the tangent plane will touch such conic surface in the whole length of one of its generating lines, and pass through the apex of the cone. If a second conic surface be supposed, containing the first and third spheres, the same tangent plane will also touch it along the length of one of its generating lines, and will consequently pass through its apex. Lastly, if a third conic surface be conceived, enclosing and touching the second and third spheres, the tangent plane will still touch it along one of its generating lines, and pass through its apex. Thus the apices of the three conic surfaces will be in the tangent plane; but they will also be in the plane which, passing through the centre of the sphere, contains the three axes: they will therefore be in two different planes at the same time; consequently, they will be in a right line. Hence it follows, that if the horizontal and vertical projections be constructed, as laid down in the preceding question, of which two will be sufficient, the projection of a line found upon the tangent plane may be made to pass through them. The question is therefore reduced to the drawing from a given right line, a tangent plane to that of the three spheres sought for, which may be done by the preceding methods, and this plane will be tangent to the two others.

"It must be observed, that, as we may always imagine, for any two spheres, two conic surfaces which envelope and touch them both, the first having its apex on the outside of one of the centres, with respect to the other, and the second having its apex between the two, it is evident, that in the preceding question there will be six conic surfaces, of which three will be on the outside of the three spheres, taken two by two, and three will have their apices between the spheres. The apices of these six cones will be distributed, three and three, upon four right lines, along each of which may be drawn two planes tangent at the same time to the three spheres. Thus eight different planes are sufficient for this question: two of which touch the three spheres on the same side relatively; and the other six are so disposed as to touch two of the spheres on one side, and the third on the other. These considerations lead to the following proposition:

"*Figure* 22.—Three circles whatever being given in position and magnitude on a plane, if, considering them two at a time, exterior tangents be drawn to them, produced till they intersect each other, the three points of intersection, D, E, F, so obtained, will be in a right line.

"Here, if we imagine the three spheres, of which these circles are the great circles, and a plane that touches them all three exteriorly, such plane will also touch the three conic surfaces contained within the spheres, considered two by two, and pass through their three apices, D, E, F; but these three apices are likewise upon the plane of the three centres; therefore they are on two different planes, and consequently in a right line.

"If to the same circles, considered two by two, interior tangents be drawn, intersecting each other, the three new points of intersection, G, H, I, will be, two by two, in a right line with the three first; so that the six points D, E, F, G, H, I, will be the intersections of the four right lines.

"This question is only a particular case of the following, which applies to all the three dimensions.

"The size and position of any four spheres being given in space, if the six conic surfaces circumscribed exteriorly by them, considered two by two, be conceived, the apices of the six cones will be in the same plane, and at the intersections of the four right lines; and if the other six conic sections, circumscribed interiorly by them, viz., that have their apices between the centres of the two spheres, be conceived, the apices of the six latter cones will be, taken three by three, in the same plane with three of the former.

"*Fourth Question.*—From an arbitrary point, to draw a tangent plane to a given cylindric surface.

"*Solution.—Figure* 23.—Let E I F K be the trace of the cylindric surface on the horizontal plane; a trace that we

suppose to be given. Let A B, *a b*, be the two given projections of the right line, to which the generating line should always be parallel; and C, *c*, those of the given point. Conceive from this point a parallel to the generating line, it will be in the tangent plane required, and the points where it cuts the planes of projection will be upon the traces of the tangent plane. Then if from the point C, C D be drawn parallel to A B, and from the point *c*, *c d* parallel to *a b*, we shall have the two projections of this right line; then, having produced *c d* till it meet L M in the point *d*, if the point *d* be projected to D, upon C D, the point D will be the coincidence of this right line with the horizontal plane, and consequently a point of the trace of the tangent plane. Now, the horizontal trace of the tangent plane ought to be tangent to the curve E I F K, therefore, if from the point D we draw to such curve all the tangents possible, as D E, D F, &c. we shall have the horizontal traces of all the tangent planes that can possibly pass through the given point. By drawing from the points of contact E, F, &c. to A B, the indefinite parallels E G, F H, &c. we shall obtain the horizontal projections of the generating lines, wherein the different planes touch the cylindric surface. Lastly, we shall have the vertical projections *e g*, *f h*, &c. of these generating lines, or lines of contact, by projecting the points E, F, &c. upon the vertical plane, to *e*, *f*, &c. and by drawing from these latter points indefinite lines parallel to *a b*. As to the traces of the tangent plane upon the vertical plane, they will be found in the working of *Figure* 12.

"*Fifth Question.*—From an arbitrary point, to draw a plane tangent to a given conic surface.

"The solution of this question differing but little from that of the preceding one, we shall only refer to the *Figure* 24, where the curve E G F H, is the given trace of the conic surface; A, *a*, are the given projections of the apex; and C, *c*, those of the given point, through which the tangent plane must pass.

"*Sixth Question.*—From a given line, to draw a tangent plane to a given revolving surface.

"*Solution.—Figure* 25. Suppose the axis of the revolving surface to be perpendicular to one of the two planes of projection (which will not weaken the general application of the solution, because we always retain the power of disposing of the position of these planes so as to make them conform to this rule); let A be the given horizontal projection of the axis of the surface; *a a'*, its vertical projection; *a p i a'*, the generating curve of the surface; and B C, *b c*, the two given projections of the line along which the tangent plane should pass. From the point A drop the perpendicular A D upon B C, and it will be the horizontal projection of the shortest distance between the axis and the given right line; and project the point D to *d*, upon *b c*.

"Now, suppose the tangent plane to be drawn, and the given right line to turn about the axis of revolution, without shifting its distance from it, or its inclination upon the horizontal plane, drawing with it the tangent plane, so that the latter may still touch the surface; in consequence of such movement, it is evident, that the point of contact of the surface with the plane will change its position; but since the tangent plane uniformly preserves the same inclination, the point of contact will not change its altitude above the surface, and it will move in the circumference of a horizontal circle, whose centre will be in the axis. The given right line, also, will generate by its movement a second revolving surface around the same axis, to which the tangent plane will itself be tangent in every position.

"If we suppose a plane through the axis, and through the point of contact of the tangent plane with the first surface, it will cut the generating line in a point wherein the same tangent plane will come in contact with the second; for besides the generating line, along which it passes in this point, it also passes along the tangent of the horizontal circle to the same point, since it likewise passes along the tangent of the horizontal circle to the point of contact with the first surface, and therefore, from the known property of revolving surfaces, these two tangents are parallel.

"As we wish to resolve the question by means of the second revolving surface, it becomes necessary to construct the curve according to which it would be cut by a plane drawn from the axis: here we will suppose such plane to be parallel to the vertical plane of projection, and consequently projected on the horizontal plane in a right line, A F, parallel to L M.

"Take upon the given right line, any point whatever, whose projections are E, *e*, and seek for the point wherein it would meet the plane of the section in its movement. Here the point will describe around the axis of revolution, the arc of a horizontal circle, whose horizontal projection will be obtained, by describing from the point A, as a centre, and at the interval A E, the arc E F, till it meet the right line A F, somewhere in a point, as F; the vertical projection of the same arc may be had by drawing from the point *e*, the indefinite horizontal line *e f*. The point F, then will be the horizontal projection of the coincidence of the describing point with the plane of the section; therefore, by projecting the point F to *f*, upon *e f*, the point *f* will be the vertical projection of this coincidence, and consequently a point of the section. By repeating the same operation for as many other points as may be wanted, taken on the given right line, we shall have so many points, *g*, *f*, *r*, *n*, through which the curve required must pass.

"Next imagine the given right line, and the tangent plane, by their simultaneous rotation about the axis, to have arrived at a position wherein the tangent plane would be perpendicular to the vertical plane of projection. Here the projection on this plane would be a right line, tangent at the same time to both the curves *a' i p a*, *g r n f;* and if all the common tangents, as *g i*, *n p*, be drawn to these two curves, we shall obtain the projections of all the tangent planes required by the question, considered in the position they have assumed, when in the course of the rotation they have successively become perpendicular to the vertical plane. The points of contact, *i*, *p*, of these tangents with the generating line of the first surface will determine the height of those of each surface with all the tangent planes: therefore, if from these points the indefinite horizontal lines *i t*, *p s*, be drawn, they will contain the vertical projections of the points of contact of the surface with the planes: and if from the point A, as a centre, and with the radii respectively equal to *i t*, *p s*, the arcs of a circle, I K, P Q, be drawn, such arcs will contain the horizontal projections of the same points. To complete the discovery, it only remains to determine upon what meridians of the revolving surface they ought to be found, to which end the points of contact, *g*, *n*, will be subservient.

"For this purpose, project the points *g*, *n*, upon A G, to G, N; from the point A, as a centre, with the intervals successively equal to A G and A N, describe the arcs G H, N O, till they intersect the right line B C in the points H, O; these arcs will express the quantity of the rotation, which for each tangent plane, the right line passing through its contacts with the two surfaces has been obliged to make, in order to transport itself into the vertical plane parallel to that of projection. We have, therefore, the horizontal projections of the same right lines, considered in their natural positions, by drawing from the point A the lines A H, A O; and the points, K, Q, where

the latter lines intersect the correspondent arcs I K, P Q, will be the horizontal projections of the points of contact of the first surface with the tangent planes drawn along the given right line.

"The vertical projections of the same points will be obtained by projecting the points K, Q, to k, q, on the respective horizontal lines $i\ t$, $p\ s$.

"The horizontal and vertical projections of the points of contact being determined, the traces of all the tangent planes may be constructed by methods similar to those already described.

"This mode may be easily generalized and applied to any surfaces generated by curves of determinate forms, and mutable as to their situation in space."

Of the Intersections of curved surfaces.

"When the generations of two curved surfaces are positively determined and understood; when the course of all the points of space through which they pass is no longer arbitrary for either; when for each of these points, one of its two projections being taken at pleasure, the other may be always constructed; if these two surfaces have any points in space common to them both, the positions of all such common points is absolutely determined; it depends on the form of the two curved surfaces and their respective positions; and is of such a nature as to be always capable of being deduced from the definition of the generations of the surfaces, of which it is a necessary consequence.

"The course of all the points common to two determinate curved surfaces, forms in general a certain curved line in space, which, in very particular cases, may be found upon a certain plane, having but a single curvature; which, in instances infinitely more peculiar, may become a right line, without any curve; and lastly, in cases still more rare, may resolve itself into a mere point; but which, in the general, is what is denominated *a curve of double curvature*, because it ordinarily partakes of the curvatures of two curved surfaces, upon each of which it is found at the same time, and forms their common intersection.

"There exists between the operations of analyses and the methods of descriptive geometry, a correspondence, of which it is here necessary to give an idea.

"In algebra, when a problem is put into equations, and we have as many equations as unknown quantities, we can always obtain the same number of equations, in each of which there enters but one of the unknown quantities; whence we gain a knowledge of the value of each of them. The operation by which this is performed, is called *elimination*, and consists in expelling, by means of one of the equations, one of the unknown numbers from all the other equations; so that by thus successively expelling all the different unknown numbers, a final equation is obtained, containing only one, whose value it ought to produce.

"The object of elimination in algebra bears a close analogy to those operations in descriptive geometry, by which the intersections of curved surfaces are determined.

"For example: suppose that in considering a point in space, and representing, by x, y, z, the distances from this point to three rectangular planes between them, a relation be established between these three distances, and that it be expressed by an equation, wherein the three quantities x, y, z, and fixed quantities enter. By virtue of this relation, the position of the point would not be determined; for the quantities x, y, z, may change their value, and consequently the point may vary in its position, without destroying the relation expressed by the equation; and the curved surface which passes through all the positions that the point may thus occupy, without abating the relation established between the three co-ordinates, is that to which the equation belongs.

"Thus, suppose a sphere, whose radius is expressed by A, have its centre in the point of intersection common to the three rectangular planes; and that in considering a certain point on the surface of the sphere, perpendiculars be supposed to fall from such point upon the three planes, and to be represented by the letters x, y, z; it is evident that the radius of the sphere, directed to the point under consideration, will be the diagonal of a rectangular parallelopiped, whose three arêtes will be x, y, z; that its square will be equal to the sum of the four squares of the four arêtes; and that we shall thus have the equation $x^2 + y^2 + z^2 = A^2$. Now, should the point change its position on the surface of the sphere, its distances, x, y, z, as to the three rectangular planes, would vary also; but its distances as to the centre would remain unaltered, and the sum of the squares of its three co-ordinates, which is always equal to the square of the radius, would still retain its first value: we should therefore have the relation between the co-ordinates of this point expressed by the equation $x^2 + y^2 + z^2 = A^2$. This equation, which answers for all the points of the surface of the sphere, and for them only, is that of the surface itself. All curved surfaces have, thus, each its equation; and though it be not always easy to express it in such simple quantities as the distances x, y, x, it is always possible to obtain it in more complex quantities, such as the inclinations of tangent planes, or the radii of curvatures: but it is sufficient for our present purpose to have conveyed our meaning by one example.

"If now, having, in x, y, z, the equations of two different curved surfaces, and supposing that for the points of the two surfaces the distances be taken to the same rectangular planes, we eliminate one of the three quantities x, y, z, the latter, for example, from the two equations; we establish first, by the similarity of these two equations, that which does not belong indiscriminately to all the points of the first surface, nor to all those of the second, with which we are occupied, but only to those of their intersection, for which each of the two equations ought to serve, because they are upon the two surfaces at the same time. Secondly, the equation in x, y, which results from the elimination of z, expresses the existing relation between the two distances for all the points of intersection, whatever may be the distance z, which has disappeared, and about which there is no longer any question in the equation; it is therefore the equation of the projection of the intersection of the two surfaces upon the plane perpendicular to z.

"Hence we discover that in algebra, the design of elimination among many equations with three unknown qualities, is to determine, upon the three planes to which all space is referred, the projections of the intersections of surfaces to which the equations appertain.

"The similitude between the operations of analysis and the methods of descriptive geometry, are not confined to the instance just given, but prevails in every situation. In working generating lines of any description in space, whatever movements be given to points, curved lines, or surfaces, they may always be governed by analytical operations; and the new objects which they originate, are expressed by the very results of such operations: on the other hand, there is no operation of analysis in three dimensions, but what is the expression of a movement operated in space, and ruled by it. To obtain the most advantageous acquaintance with the mathematics, the student should early accustom himself to perceive the existing analogy between the operations of

analysis and those of geometry: on the one hand, he should be able to write down all the movements that he can conceive in space, in one analytical method; and on the other, to perpetuate upon his memory, the object moving in space, of which each of the analytical operations is the expression.

"We now return to our subject, viz., the mode of determining the projections of the intersections of curved surfaces.

"To present the exposition of this method in a clearer light, we shall not at first disclose it with all the elegance of which it is susceptible, but proceed towards it by degrees. And here it may be premised, that the exposition will be general, and applicable to any two surfaces whatever; and that though the letters used refer to the *Figure* 26, which shows the particular case of two conic surfaces, with circular bases and vertical axes, the reader should keep in mind, that the surfaces under consideration may be, each one in particular, any other than conic surfaces.

"*First general problem.*—The generating lines of two curved surfaces being known, and all the given lines which fix such generators being determined on the plane of projections; to construct the projections of the curve of double curvature, according to which the two surfaces intersect each other.

"*Solution.—Figure* 26. Conceive a series of indefinite planes, conveniently disposed in space; such planes, for example, may be all horizontal, as in fact we shall suppose them in the first instance. Here the vertical projection of each of them will be an indefinite horizontal right line; and as we are not restrained from drawing them at arbitrary distances, we shall suppose in the vertical projection as many horizontal lines, $e\,e'$, $e\,e'$, $e\,e'$, &c. as we please, and that the series of these lines is the vertical projection of the series of planes at first conceived. This done, work successively, for each of such planes, and relatively to the line $e\,e'$, which is its projection, the operation we are about to lay down for the one among them, that is projected in E E′.

"The plane E E′ will intersect the first surface in a certain curve, which will be easily constructed, when we are acquainted with the generation of the surface; it being the course of the points in which the plane E E′ is intersected by the generating line in all its positions. This curve being plain and horizontal, will have its horizontal projection equal, similar to itself, and placed in the same manner; it is therefore possible to construct such projection, and here we shall suppose it to be the curve F G H I K.

"The same plane, E E′, will likewise cut the second surface in another plain horizontal curve, whose horizontal projection may also be constructed, as by the curve F O G.

"It may happen, that the two curves, wherein the same plane, E E′, intersects the two surfaces, may intersect each other, or they may not: if they do not intersect each other, however much produced, it proves that, at the height of the plane E E′, the two surfaces have no common point; but if these curves do intersect each other, they will do so in a certain number of points common to the two surfaces, which are consequently so many of the points of intersection required: and according as the intersecting points of the two curves are upon the first or second of them, so are they upon the first or second of the surfaces proposed; therefore, if they be upon the two curves at once, they are also upon the two surfaces.

"As the horizontal projections of the points wherein the two curves intersect each other, should be found both on the projection of the first, and on that of the second; the points F, G . . . . of the coincidence of the two curves F G H I K, and F O G, will be horizontal projections of as many points of the required intersection of the two curved surfaces. To obtain the vertical projections of the same points, observe that they are all comprised in the horizontal plane E E′, and that their projections must fall upon the line E E′. Therefore, by projecting the points, F, G . . . . upon E E′, to f, g. . . we shall have their vertical projections.

"By pursuing the same operation for all the other horizontal lines $e\,e'$, $e\,e'$, we shall obtain for each of them, in the horizontal projection, a series of new points, F, G. . . . ., &c., and in the vertical projection, another new series f, g . . . . &c. Then if the branch of a curve be passed through all the points F . . ., another branch through all the points G. . . . ., and so of the rest, the concourse of all these branches which may possibly meet one in another, will be the horizontal projection of the two surfaces; in like manner, if through all the points f . . . . a branch of a curve be passed, through all the points g . . . . another branch, and so of the others, the concourse of all these branches, which may likewise possibly meet one in another, will be the vertical projection of the intersection required.

"This method is general, even supposing a system of planes to be chosen which intersect a series of horizontal planes. But we shall see, presently, that in certain cases, the choice of the system of intersecting planes is not indifferent, that it may sometimes be so made as to be productive of systems more easy and more elegant; and that it may even be more advantageous, instead of a system of planes, to adopt a series of curved surfaces, which vary from each other only in one of their dimensions.

"To construct the intersection of two revolving surfaces, whose axes are vertical, the most advantageous system of planes, is a series of horizontal planes; for each of such planes intersects the two surfaces in the circumferences of circles whose centres are upon the respective axes, whose radii are equal to the ordinates of the generating curves, taken at the height of the intersecting plane, and whose horizontal projections are circles of known size and position. Here all the points of the horizontal projection of the two surfaces are found by the intersections of the arcs of a circle; and we are aware, that if all the revolving surfaces had their axes relatively parallel, but not vertical, it would be necessary to change the planes of projection, and so to choose them as that one of them should be perpendicular to the axes.

"Were it required to construct the intersection of two conic surfaces, with whatever bases, whose traces on the horizontal plane were given or constructed, the system of horizontal planes would demand operations too tedious for the example: for each of the horizontal planes would intersect the two surfaces in curves, which, though very nearly resembling the traces of the respective surfaces, would not be equal to them; they must be constructed by points, each by itself; whereas, if after having drawn a right line through the given apices of the two cones, the system of planes passing along such right line be adopted, each of the planes will cut the two conic surfaces in four right lines; and these right lines, which will be in the same plane, will cut each other, independently of the apices, in four points upon the intersection of the two surfaces. In this case, each of the points of the horizontal projection of the intersection will be constructed by the intersection of two right lines.

"For two cylindric surfaces, of whatever bases, whose generating lines are diversely inclined, the system of horizontal planes would not be the most eligible that might be adopted. They would, indeed, each cut the two surfaces in curves similar and equal to their respective traces; but the curves that did not correspond vertically to the traces would have for their projections, curves, that would be distant from

the traces themselves, and which it would be necessary to construct from points. But were choice to be made of the system of planes parallel at the same time to the generating lines of the two surfaces, each of such planes would cut the two surfaces in right lines, and these lines would cut each other in points appertaining to the intersection of the two surfaces. By this means, the points of the horizontal projection would be constructed by the intersections of right lines. Indeed, this is but a necessary consequence of what has been said relative to the case of two conic surfaces.

"For two revolving surfaces, having their axes in the same plane, but not parallel to each other, the system of spherical surfaces having their common centre in the point of coincidence of the two axes, would be preferable to that of planes; for each of the spherical surfaces would cut the two revolving surfaces in the circumferences of two circles, having their centres upon the respective axes, and their planes perpendicular to the plane drawn along the two axes: the intersecting points of these two circumferences, which would be at the same time on the spherical surface and upon the two revolving surfaces, would belong to the intersection required. Thus the points of the projection of the intersection would be constructed by the coincidence of the circles with the right lines; in which case the most advantageous position for the two planes of projection is to have one perpendicular to one of the axes, and the other parallel to both.

"These few observations, with respect to such curved surfaces as most frequently meet together, will suffice to show how the general method should be employed, and how, by a knowledge of the generation of curved surfaces, that species of sections may be adopted which will yield the most ready constructions.

"When the respective form and positions of two curved surfaces are defined, not only is the curve of their intersection in space determined, but also all the affections of these curves immediately follow. Thus, for example, in each of their points the direction of their tangent is determined: it is the same as to their normal plane, viz., of the plane that cuts the curve in a right angle, and which is, consequently, perpendicular to the tangent at the point of intersection. As we shall have frequent occasion to consider planes normal to curves of double curvature, we shall not here enter into any detail as to their determination; for as they are always perpendicular to tangents, it is enough to have given the mode of constructing projections of tangents to the intersections of curved surfaces.

"*Second general Problem.*—From a point taken at pleasure upon the intersection of two curved surfaces, to draw a tangent to such intersection.

"*Solution.* The point chosen upon the intersection of two curved surfaces, is at the same time upon both such surfaces. If then, from this point, as considered on the first surface, a tangent plane be drawn to such surface, it will touch the intersection in the point in question. So, likewise, if from the same point, as considered on the second surface, a tangent plane be drawn to such surface, the plane will touch the intersection in the point under consideration. The two planes, then, will touch the intersection in the same point, which will also be one of their common points, and consequently one of those of the right line in which they intersect each other: therefore, the intersection of the two tangent planes will be the tangent required.

"From this problem arises the following observation, which is of great utility in descriptive geometry.

"The projection of the tangent of a curve of double curvature is itself tangent to the projection of a curve; and its point of contact is the projection of that of the curve of double curvature.

"Thus, if from all the points of the curve of double curvature, perpendiculars be supposed to fall upon one of the planes of projection, as upon the horizontal plane, for example, all such perpendiculars will be upon a vertical cylindric surface, which will be cut by the horizontal plane in the very projection of the curve. In like manner, if, from all the points of the tangent to the curve of double curvature, vertical lines be supposed to drop, they will be in a vertical plane, intersected by the horizontal plane in the projection of the tangent. Now, the cylindric surface and the vertical plane evidently touch each other in the whole extent of the vertical line dropped from the point of contact, and which is common to them both: the intersections, therefore, of the cylindric surface, and of the plane along the horizontal plane, touch each other in a point that will be the intersection of the line of contact of the cylindric surface and the vertical plane. Consequently, the projections of a curve of double curvature and of one of its tangents will touch each other in a point that is the projection of the point of contact of the curve.

"We shall now proceed to apply what has been said to some particular cases; and to begin with simple considerations, we shall first suppose one of two surfaces to be a plane, whose intersection we would determine.

"*First Question.*—To construct the intersection of a given cylindric surface with a plane of a given position.

"The position of planes of projections being arbitrary, we will first suppose, what is always possible, that these two planes have been so chosen as to have one perpendicular to the generating line of the surface, and the other perpendicular to the cutting plane; for in this supposition the construction is much more easy; and then to give to students a habit of making projections, we will suppose the two planes of projection in any other manner.

"*Solution.* First case, in which the generating line of the surface is supposed to be perpendicular to one of the planes of projection, as to the horizontal plane, for example, and the cutting plane perpendicular to the other.

"*Figure* 27.—Let A be the horizontal projection of the right line, to which the generating line of the cylindric surface should always be parallel; $a\,a''$ its vertical projection; B C D E, the given trace of the cylindric surface, which being the horizontal projection of the indefinite surface, is consequently that of the curve of intersection; let $f\,g$ be the given vertical projection of the cutting plane, which will also be that of the intersection required; and F G the horizontal trace of the same plane. It is evident, that if we draw to the curve B C D E, and perpendicular to L M, the indefinite tangents E e'', C c'', the right lines $e\,e''$, $c\,c''$, will be the vertical projections of the generating line, in its extreme positions; and that the points e', c', in which they intersect the projection, $f\,g$, of the cutting plane, will terminate upon $f\,g$, the vertical projection of the required intersection.

"Now, if from a point taken arbitrarily upon the intersection (a point whose horizontal projection will be a point, H, taken at pleasure on the curve B C D E, and whose vertical projection may be had by projecting the point H in i', upon $f\,g$) we would draw to this intersection, it is also evident that such tangent should be comprised in the cutting plane, and that its vertical projection would be the right line $f\,g$; also, that it would be comprised in the vertical tangent plane to the cylindric surface, and that its horizontal projection, which will be the same with that of the tangent plane, would be the right line F H N, tangent in H to the given curve B C D E. Thus all is determined as to the intersection required.

"Now, should it be required to construct this intersection such as it exists in its plane, and from one of its points, taken at pleasure, to draw a tangent to it: if the vertical plane of projection be at too great a distance from the curve B C D E, we may suppose another vertical plane, parallel to it, passing through the interior of the curve B C D E, and whose horizontal projection should be the right line E C, parallel to L M. This vertical plane will intersect the cutting plane in a right line parallel to its projection $f\,g$, and upon which, as upon a hinge, we will suppose the cutting plane to turn, to become vertical, and to present in full front the curve required. Then, from as many points, H, as may be thought convenient, taken arbitrarily upon B C D E, suppose vertical planes perpendicular to the vertical plane of projection, whose horizontal and vertical projections will both appear at the same time, in drawing through all the points H, the right lines H J K $i\,i'$ perpendicular to L M. Each of these planes will intersect the cutting plane in a horizontal line, perpendicular to the hinge, whose vertical projection will be the point of coincidence, i', of two right lines $f\,g$, $i\,i'$. In each plane this horizontal line will meet the hinge in a point, whose horizontal projection will be the intersection, J, of the two right lines E C, H J K, $i\,i'$; and will also meet the curve required in points, whose horizontal projections will be the intersections H, K, of the right line H J $i\,i'$ with the curve B C D E. In a word, this right line and all its parts will be equal to their horizontal projections. Now, when the cutting plane turns upon the hinge, to become vertical, all these right lines, which were at first horizontal, remain perpendicular to the hinge, and do not vary in size. Therefore, if through all the points i', we draw indefinite perpendiculars, $h\,k$, to $f\,g$, and if upon these perpendiculars J H be transferred from i' to h, and J K from i' to h, we shall have as many points, h, k, as we wish for, through which the required curve, $e'\,k\,c'\,h$, may be drawn.

"The curve being constructed in its plane, if it be required, from one of its points, h, taken arbitrarily, to draw a tangent to it, we may obtain the vertical projection of such point, by dropping from the point h, upon $f\,g$, the perpendicular $h\,i'$; and its horizontal projection, by projecting i' in H upon the curve B C D E; we shall have the horizontal projection of the tangent required, by drawing the right line F N tangent in H to the curve B C D E; and it will be sufficient to bring into the plane of the curve any point whatever of the tangent; as that, for example, which is projected on the point N taken arbitrarily, and whose vertical projection is upon $f\,g$ in a'. Now, in making our deductions upon this point, as upon every other of the cutting plane, it cannot but be obvious, that if through the point a', we draw to $f\,g$ the perpendicular $a'\,n$ and that if upon this right line we transfer from a' to n the distance N A from the point N to the right line E C, the point n will be the second of the tangent. Therefore by drawing the line $h\,n$ we shall have the tangent required.

"Whatever curve be given to B C D E, we see that the intersection $e'\,k\,c'\,h$ possesses the property of having for either of its points the sub-tangent $a'\,n$ equal to the sub-tangent A N of the first. This property, which is very well known in the circle and ellipsis, when those two curves have a common axis, arises, with respect to them only, from their being the intersections of one cylindric surface through two different planes.

"Lastly, it may occur, that we shall want to trace upon the development of the cylindric surface, the effect of the section made by the cutting plane. For this purpose, after having developed the curve B C D E, with all its divisions, upon a right line R Q; if indefinite perpendiculars be drawn through all the divisions of R Q, we shall have, upon the development of the surface, the traces of the different positions of the generating line, and we shall then only have to transfer upon these perpendiculars the parts of the corresponding generating lines, comprised between the perpendicular section B C D E, and the section made by the cutting plane. Now, these parts of generating lines are equal to their vertical projections, and these projections are all terminated, on one hand, by the right line L M, and on the other by $f\,g$. If then the point H, for example, fall in S, upon the line R Q, by transferring $i\,i'$ upon the perpendicular passing through the point S, from S to T, the point T will be, upon the developed surface, that where the generating line, which passes through the point H, is intersected by the cutting plane. The curve X T Y Z, which passes through all the determinate points in the same manner, will be the curve required.

"It is obvious, that were the tangent produced from the point H till it meet the horizontal trace, G F, of the cutting plane, somewhere in a point, F; and that if H F were transferred upon R Q, from S to U, the right line T U would be tangent to the curve; for when the cylindric surface is developed, its elements do not alter their inclination with respect to the horizontal plane.

"*Second Case*, wherein the cylindric surface and the cutting plane are supposed to be in any manner whatever with respect to the two planes of projections.

"*Solution.—Figure* 28. Let A A′ and $a\,a'$ be the two projections of the right line, to which the generating line should be parallel; C E D F, the given trace of the cylindric surface; and H G, $h\,b$, the traces of the cutting plane.

"Conceive a series of planes parallel to the generating line of the cylindric surface, and also perpendicular to one of the planes of projection, as the horizontal plane, for example: each of such planes would be projected upon a right line, O K E, parallel to A A′, cutting the surface in right lines that would be so many positions of the generating line, and would meet the horizontal plane in the points of intersection, E, F, of the line O K E with the curve C E D F. By projecting, therefore, the points E, F, upon L M, in e, f, and drawing through these latter, to the right line $a\,a'$, the parallels $e\,e'$, $f\,f'$, the vertical projections of the intersections of the surface with each of the planes parallel to the generating line will be obtained.

"The same planes will likewise intersect the cutting plane in right lines, parallel to each other, all whose horizontal traces will be upon the different points, O, of the line G H, and whose vertical projections will be also parallel to each other. To obtain these projections, we must first find the direction of one of them, of that, for example, which corresponds to the vertical plane drawn from A A′. With this view, produce A A′ till it meet, on one hand, the trace of the cutting plane in a point N, and on the other, the right line L M, in a point B, and by projecting the point B in b on $h\,b$, the two points N and b will be, upon the two planes of projection, the traces of the intersection of the cutting plane with the vertical one. By projecting the point N in n upon L M, and drawing the line $n\,b$, it will give the vertical projection of this intersection. By projecting on L M all the points, O, in which the trace G H is cut by the projections of the vertical planes, which will give a series of points o, and drawing from the latter the parallels $o\,i\,k$, to $n\,b$, the vertical projections of the intersections of the cutting plane, through the whole series of the vertical planes, will be obtained. Lastly, the points of coincidence, i, k, of each right line $o\,i\,k$ with the projections $e\,e'$, $f\,f'$, of the sections made in the cylindric surface by the corresponding vertical plane, will be the vertical projection of the intersection required; and the curve that

would pass through all the points, i, k, thus determined, would be that projection. By projecting the points i, k, in J, K, on the projection, O K E, on the corresponding vertical plane, we shall have the horizontal projection of the same points, and the curve, K J P, that would pass through all the points so determined, would be the horizontal projection of the intersection.

"In seeking the tangents of these two projections to the points J, i, it must be recollected that such tangents are projections of the tangent to the intersection. Now, the latter tangent being at the same time in the cutting plane and in the tangent plane to the cylindric surface, it must have its horizontal trace in the intersection of the horizontal traces of the two planes: the trace of the tangent plane is also the tangent in F to the curve C E D F. Therefore, by drawing this tangent, and having produced it till it meet the trace of the cutting plane in a point G, drawing the right line G J, we shall have the latter line touching, at the point J, the horizontal projection of the intersection. And by projecting the point G upon L M in g, and drawing the right line g i, we shall obtain the tangent, in i, of the vertical projection of the same curve.

"Should it be required to construct the curve of the intersection as it is in the plane, suppose the cutting plane to turn upon its horizontal trace H G, as upon a hinge, and applying itself to the horizontal plane. In this movement, each of the points of the section, that, by way of example, which is projected in J, will describe an arc of a circle, whose plane will be vertical, perpendicular to H G, and whose indefinite projection will be obtained by drawing through the point J a right line, R J S, perpendicular to H G; consequently, when the plane is laid down, the point of the section will fall somewhere upon a point of this right line. To discover the distance of such point from the hinge: as the horizontal projection of this distance is J R, and the difference of the heights of its extremities is the vertical line i s; if J R be measured upon L M, from s to r, the hypothenuse r i will be such distance. Then by measuring r i upon R J, from R to S, the point S will be one of the points of the intersection considered, with its plane laid down upon the horizontal plane, and the curve S T U V, drawn through all the points S constructed alike, will be the intersection itself.

"To obtain the tangent of this curve to the point S, it is sufficient to observe, that in the movement of the cutting plane, the tangent does not cease to pass through the point G of the hinge; therefore, by drawing the right line S G, we shall have the tangent required.

"*Second Question.*—To construct the intersection of a conic surface, of any given base, by a plane given in position.

"*Solution.*—Here we may suppose, what is always possible, the vertical plane of projection to be placed perpendicular to the cutting plane.

"*Figure* 29.—Let A, a', be the projections of the apex of the cone, or of the centre of the conic surface; B C D E the trace of such surface on the horizontal plane; f g the vertical projection of the cutting plane; and G f its horizontal trace. Suppose from the apex of the cone a series of planes, perpendicular to the vertical plane of projection; the vertical projections of such planes will be the right lines a' c, drawn from the projection of the apex: and their horizontal traces will be the right lines c C, perpendicular to L M, which will cut the trace of the conic surface somewhere in the points C, C' . . . . These planes will cut the surface in right lines, whose vertical projections will be the lines a' c . . . ., and whose horizontal projections will be obtained by drawing from the point A, the lines C A, C' A . . . .; the same planes will likewise intersect the cutting plane in lines perpendicular to the vertical plane. The projections of such lines will be the points, h . . ., of coincidence of f g, with the lines a' c . . . ; and their horizontal projections will be obtained by dropping, from the points h . . . ., upon L M, the indefinite perpendiculars h H . . . . This done, the lines h H . . . . will cut the corresponding lines C A, C' A . . ., in points, H, H' . . . ., which will be the horizontal projections of so many of the points of intersection required; and the curve, P H Q H', that would pass through all the points thus constructed, will be the projection of the intersection.

"To draw a tangent to this curve, from a point H, fixed upon at pleausre, it is only requisite to find upon the horizontal plane the trace of the tangent of the intersection in a point corresponding to H. This trace must be upon that of the cutting plane, and consequently on G f; it must also be upon that of the plane touching the conic surface in the right line, whose projection is A H: and if A H be produced till it meet the curve B C D E somewhere in a point C, the tangent, C F, of this curve, in the point C, will be the horizontal trace of the tangent plane. The point, F, of coincidence of the two traces f G, C F, will therefore be upon the tangent in the point, H, of the curve P H Q H'.

"Should it be required to construct the intersection considered in its plane, we may indefinitely suppose either that the cutting plane turns upon G f, as upon a hinge, in order to apply itself to the horizontal plane, and so construct the curve in the position it will thus assume; or that it turns upon its vertical projection f g, to apply itself to the vertical plane; the latter is the hypothesis we shall here adopt.

"All the horizontal lines in which the series of planes drawn from the apex has intersected the cutting plane, and which are perpendicular to f g, do not change their size in the movement of the cutting plane, nor do they cease to be perpendicular to f g: if then indefinite perpendiculars be drawn through all the points h, to f g; and if upon them the corresponding horizontal lines K H, K H', be measured and applied from h, to N and N', the points N, N', will be those of the section; and the curve R N S N', drawn through all the points thus constructed, will be the intersection considered in its plane.

"From all that has been said, it appears evident, that, to draw to this curve a tangent in a point, N, taken arbitrarily upon it, the perpendicular N h must be dropped from the point N upon f g; that the right line a' h must be produced till it meet L M in the point c; that this point must be projected in C, or the curve B C D E; that the tangent must be drawn to such curve in C, cutting the trace G f somewhere in a point F; and that F f must be carried perpendicularly to f g, from f in O. The right line O N will be the tangent required.

"As to the mode of constructing the development of the conic surface, of whatever base, and of tracing thereon the effect of the intersection with the cutting plane, we shall proceed to describe it, after having spoken of the intersection of the conic surface with that of a sphere having its centre in the apex.

"To construct the intersection of two conic surfaces with circular bases, whose axes are parallel to each other.

"*Solution.*—*Figure* 26. As it would be superfluous here to repeat what has already been said in treating of the general method, of which this figure was a type; we shall only observe, that in the case now before us, as well as in that of two revolving surfaces, of whatever description, the sections made in the two surfaces by the horizontal planes, are circles; but we shall enter upon some details relative to tangents, of which we have not yet had occasion to speak.

"To discover the tangent to the point D (*Figure* 26) of the horizontal projection of the intersection, we must recollect that it is the projection the tangent of the intersection of the two surfaces, in the point of corresponding to D, and that to determine it, it is only necessary to find the point S, which is, upon the horizontal plane, the trace of the tangent of the intersection. This latter tangent is in the two planes which touch the conic surfaces in the point of intersection; therefore, by finding the horizontal traces R r, Q q, of these two tangent planes, they will by their coincidence, determine the point S. But the plane tangent to the first surface touches it in a line that passes through its apex, whose horizontal projection may be obtained by drawing the indefinite right line A D. And if A D be produced till it meet the horizontal circular trace of the surface, T Q U V, in a point, Q, such point will be a point of the line of contact between the surface and the plane; consequently, the horizontal trace of the plane will be tangent in Q to the circle T Q U V: let this tangent therefore be drawn, as Q q. In like manner, by producing the radius B D till it meet in R the circular horizontal trace, R X Y Z, of the second surface, and drawing to this circle the tangent in R, the line R r will be the horizontal trace of the plane tangent to the second surface. And if from the point S, of the intersection of the two tangents Q q, R r, the right line S D be drawn, it will give the tangent, in the point D, of the horizontal projection of the intersection.

"With respect to the tangent to the corresponding point d, of the vertical projection, it is obvious that it may be obtained by projecting the point S in s, and by drawing the line s d, which will be the tangent required.

"It may happen to be necessary to construct upon the development of one of the conic surfaces, perhaps, even upon that of each of them, the effect of their mutual intersection; as, for example, if we were obliged to fabricate the cones of flexible substances, such as metal plates: in this case we must operate for such cone in the manner we are going to prescribe for the first.

"Before we proceed, let it be observed, that when a conic surface is developed so as to become a plane, the right lines that are upon it, change neither their form nor size, because each of them is successively the hinge upon which the development acts; so that all the points of the surface remain always at the same distance from the apex. And when, as in this case, the conic surface is direct and circular, all the points of the circular horizontal trace are at equal distances from the apex; they must, therefore, be also at an equal distance from the apex upon the development, and consequently upon the arc of a circle, whose radius is equal to the uniform distance of the apex from the circular trace. And if, after having taken an arbitrary point to represent the apex on the development, the arc of an indefinite circle, whose radius is equal to a C, be described, having such point for its centre, it will also be indefinitely the development of the horizontal trace of the surface. Then, by measuring the arc of the circle T Q on the are just described, beginning from the point T of the trace from which it is designed to begin the development, the position of the point Q upon the development will be determined; and the indefinite right line drawn from this point to the centre of the development, will be the position occupied by the right line of the surface projected in A Q, and upon which the point D d, of the section referred to, will be found. To construct this point, it only remains to discover its distance from the apex, and to measure it upon the indefinite right line, beginning from the centre of the development. In order to this, draw the horizontal line d k, from the point d in the vertical projection, till it cut the side a C of the cone, in a point k, and the line a k will be the distance sought for. By constructing, in like manner, all the other parts of the intersection, successively, and passing a curve through them, the intersection of the two surfaces described upon the development of the first surface will be found. Proceed in the same manner for the second surface.

"*Fourth Question.*—To construct the intersection of two conic surfaces, of whatever basis.

"*Solution.*—*Figure* 30. Let A, a, be the projections of the apex of the first surface; C G D G′, its given trace upon the horizontal plane; B b, the projections of the apex of the second surface; and E H F H′, its trace on the horizontal plane. Suppose a right line passing through the two apices, whose projections are the indefinite lines A B, a b, and whose trace, I, may be easily constructed upon the horizontal plane. Along this line conceive a series of planes, each cutting the two conic surfaces in the system of several right lines; and such of these right lines as shall be in the same plane will determine, by their intersections, so many points of the intersection of the two surfaces. The horizontal traces of all the planes of this series will necessarily pass from the point I; and since the position of these planes is besides arbitrary, their traces may likewise be taken arbitrarily, by drawing from the point I, a number of lines, I K, at pleasure, by each of which the following operation may be worked for either of them.

"The trace, K I, of each of the planes of the series will cut the horizontal trace of the first conic surface in points, G G′, which will also be the horizontal traces of the right lines, according to which the plane cuts the conic surface: thus A G, A G′, will be the indefinite horizontal projections of these lines, and their vertical projections will be obtained by projecting G, G′, in g, g', and drawing the indefinite lines a g, a g'. So likewise, the trace, K I, of the same plane of the series will cut the horizontal trace of the second conic surface in points, H, H′, from which if B H, B H′, be drawn indefinitely, the horizontal projections of the lines will be obtained, according to which the same plane of the series will cut the second surface; and their vertical projections may be had, by projecting H, H′, in h, h', and drawing the indefinite lines b h, b h'.

"This done, for the same plane, whose trace is K I, we shall have on the horizontal projection a certain number of lines, A G, A G,′ B H, B H′; and the points, P, Q, R, S, in which those belonging to one of the surfaces, meet those belonging to the other, will be the horizontal projections of so many points of the intersections of both surfaces. Thus, by working successively, in the same manner, upon the other lines K I, we shall find new series of points, P, Q, R, S; and by afterwards passing through all the points P, a first branch of a curve, through all the points Q, a second, through all the points R, a third, &c., we shall have the horizontal projection of the intersection required.

"In like manner, for the same plane, whose trace is K I, we shall have upon the vertical projection a certain number of lines a g, a g', b h, b h', whose points of intersection will be the vertical projections of as many points of the intersection.

"Here let it be remarked, that it is not necessary to construct the two projections independently of each other, and that having constructed a single point of one of them, it may be projected in the other upon one of the lines that ought to contain it: hence we acquire means of verifying the operation, and of avoiding, in certain cases, the intersections of lines which cut each other in angles too oblique.

"To find the tangents to the horizontal projection, that, for example, which touches it in the point P, we must

construct the horizontal trace, T, of the tangent of the intersection in the point corresponding to P. This tangent is the intersection of the two planes which touch the conic surfaces in that point; its trace, therefore, will be in the coincidence of the horizontal traces with such two tangent planes. And as A G′ P is the projection of the line of contact of the plane which touches the first surface, the trace of such first plane will be the tangent to the curve C G D G′, in the point G′: let then G′ T V be that tangent. So likewise B H′ P is the horizontal projection of the line of contact of the plane that touches the second surface; and as the horizontal trace of the second tangent plane will be the tangent, in the point H′, of the curve E H F H′, let H′ T U be such tangent. The two tangents G′ V, H′ U, will intersect each other in a point, T, from which if the line T P be drawn, we shall have the tangent in the point P, as required.

"By proceeding in like manner with the other points Q, R, S, we shall find, first, that the tangent in Q must pass through the point of coincidence of the tangents in G′ and H; secondly, that the tangent in R must pass through the coincidence of those in H and G; and, thirdly, that the tangent in S must pass through the coincidence of those in G and H′.

"Tangents of the vertical projection are attended with no difficulty, when those of the horizontal projection are once determined; for by projecting the horizontal traces of the tangents of the intersection, we have the points through which they must pass.

"*Fifth Question.*—To construct the intersection of a conic surface of any base, with that of a sphere.

"We shall here suppose the two surfaces to be concentric, that is to say, the apex of the cone placed in the centre of the sphere, because we shall have occasion for such a disposition in the following question.

"*Solution.*—*Figure* 31. Let A, *a*, be the projections of the common centre of the two surfaces; B C D E, the given horizontal trace of the conic surface; *a m*, the radius of the sphere; and the circle, *l f′ g′ m*, the vertical projection of the sphere. Suppose from the centre common to the two surfaces, a series of planes, which may likewise be conceived to be all perpendicular to one of the two planes of projection: in the *Figure* 31, we have supposed them to be vertical. Each of such planes will cut the conic surface in a system of right lines, and the surface of the sphere in the circumference of one of its great circles; and for each plane, the coincidence of these lines with the circumference of the circle will determine the points of the intersection required: draw, therefore, from the point A as many indefinite right lines, C A E, as you please, and they will be the horizontal projections of so many vertical planes in the series, and, at the same time, those of the lines according to which these planes cut the two surfaces. Each right line C A E, will intersect the horizontal trace B C D E of the conic surface in points, C, E, that will be the horizontal traces of the sections made in this surface by the corresponding plane; and if, after having projected the points C, E, upon L M, in *c*, *e*, the lines *a c*, *a e*, be drawn, they will give the vertical projections of the same sections.

"It now remains to discover the points of intersection of these sections with those of the sphere, upon the same plane.

"For this purpose, having drawn through the point A, the right line G A F, parallel to L M, suppose the vertical plane drawn through C E, to turn about the vertical line raised from the point A, and projected in *a′ a*, as upon a hinge, till it become parallel to the vertical plane of projection, and that it also draw with it the sections it has made in the two surfaces. In this movement, the points C, E, will describe around the point A, as a centre, the arcs of circles C G, E F, and will fall in, in G, F; by projecting the latter points upon L M, in *g*, *f*, the right lines *a g*, *a f*, will be the vertical projections of the sections made in the conic surface, considered in the new position they have assumed in consequence of the movement of the plane. The section made in the surface of the sphere, considered also in its new position, will have the circumference *l f′ g′ m* as a vertical projection. The points, therefore, of coincidence, *g′ f*, of this circumference with the lines *a g*, *a f*, will be the projections of the points of intersection required, considered also in the new position of the plane.

"Now, to obtain the projections of the same points, in their natural position, the vertical plane must be supposed to be returned to its original situation. In this movement, all its points, and consequently those of the intersection contained in it, will describe the arcs of horizontal circles around the vertical line raised from the point A as an axis, whose vertical projections will be horizontal lines. Then by drawing through the points *f′ g′*, the horizontal lines *f′ h*, *g′ i*, they will contain the vertical projections of the points of intersection: but these projections must also be upon the respective right lines *a c*, *a e*, and will be found in the points of coincidence, *i h*, of the latter, with the horizontal lines *g′ i*, *f′ h*. Thus the curve *k h n i*, drawn through all the points constructed in the same manner for any other line, besides C E, will be the vertical projection of the intersection required.

"By projecting the points, *i*, *h*, upon C E, in J, H, we shall have the horizontal projections of the same points of the intersection; and the curve K H N J drawn through all the points, J H, constructed in the same manner for any line besides C E, will be the horizontal projection of the intersection.

"To find the tangent to the point J of the horizontal projection, the horizontal trace P of the tangent to the corresponding point of the intersection must be constructed. This trace must be in the coincidence of the traces of the planes tangent to the two surfaces, in the point of the intersection corresponding to the point J. Here it is obvious, that by drawing C P through the point C, tangent to the curve B C E D, we shall have the trace of the plane tangent to the conic surface. And for that of the plane tangent to the surface of the sphere, the operation is similar to what has been described in the cases of revolving surfaces, *viz.* by drawing *g′ o* through the point *g′*, tangent to the circle *l f′ g′ m*, produced to the right line L M, in *o*, afterwards measuring *a′ o* upon C E, from A to O, and drawing the line O P, through the point O, perpendicular to C E. The two traces C P, O P, then will cross each other in a point, P, through which, if J P be drawn, it will be the tangent to the point J.

"Hence we see that the tangent to the point *i* of the vertical projections of the intersection will be obtained by projecting the point P upon L M in *p*, and afterwards drawing the right line *i p*, which is the tangent required.

"If the sphere and the conic surface were not concentric, it would be necessary to conceive a right line passing through their two centres, and to choose a series of cutting planes that should pass through such line. Each of these planes would cut the conic surface in right lines, and that of the sphere in one of its great circles, as in the preceding instance; which would give an equally simple construction: but then it would be advantageous to place the vertical plane of projection parallel to the right line drawn through the two centres, in order that, in the movement given to each cutting plane to render it parallel to the vertical plane of projection, the two centres may remain motionless, so as not to change their projections; by this means the constructions are simplified.

"*Sixth Question.*—To construct the development of a

conic surface, of any base, and to represent upon the surface so developed, a section, whose two projections are given.

"*Solution.*—Suppose the surface of a sphere, whose radius is taken at pleasure, whose centre is placed in the apex of the cone, and construct, as in the preceding question, the projections of the intersections of the two surfaces. This done, it will appear evident, that all the points of the spherical intersection being at the same distance from the apex, they must likewise, upon the surface developed, be at an equal distance from the apex, and consequently upon an arc of a circle described from the apex as a centre, with a radius equal to that of the sphere.

"Thus, supposing the point R (*Figure* 33) to be the apex of the surface developed, if from this point, as a centre, with a radius equal to $a\ m$ (*Figure* 31) the arc, S T U, of an indefinite circle be described, it is upon this arc that all the points of the spherical intersection will fall, so that the points of such arc will be respectively equal to the corresponding points of the spherical intersection. It therefore now remains, (after having taken at pleasure a point by way of origin, as, for example, the one projected in N, n (*Figure* 31), and a point S (*Figure* 33) to correspond with it on the surface developed) to develop the different arcs of the spherical intersection, and to measure them successively upon the arc of the circle S T U, from S, in certain points T. To do which, the spherical surface being of double curvature, it must be successively deprived of its two curvatures, without, however, altering its size, in the following manner.

"The spherical intersection being projected on the horizontal plane in N J K H, (*Figure* 31) it may be considered as traced upon the surface of a vertical cylinder, whose base would be N J K H: this surface may then be developed as directed in *Figure* 27, and the spherical intersection may be described upon it by developing the arc N J (*Figure* 31) in N′ J′ (*Figure* 32), and carrying the vertical line $i'\ i$ (*Figure* 31) perpendicularly to N′ N′ (*Figure* 32) from J′ J″. The curve N″ J″ K″ N″, passing through all the points, J″, thus determined, will be the spherical intersection, freed from its horizontal curvature, without having changed its length. The tangent to the point J″ of this curve will be obtained by carrying J P (*Figure* 31) measuring it upon N′ N′ (*Figure* 32) from J to P′, and drawing the right line J″ P′.

"Now, we shall develop the curve N″ J″ K″ H″ N″, in order to fold it on the arc S T U (*Figure* 33): for example, measure the arc N″ J″ from S to T, and the point T will be on the conic surface developed, the point in which that of the spherical intersection will apply, whose projections are J, i (*Figure* 31.) Therefore by drawing the right line R T we shall have upon the development of the surface, the generating line, whose horizontal projection is A C (*Figure* 31). Lastly, should any point be found upon this generating line, that should be brought upon the surface developed, it will be only requisite to take the distance (*Figure* 31) of such point from the apex of the conic surface, and to carry it (*Figure* 33) upon R T, from R to V; and the point V will be upon the surface developed, the one required.

"*Seventh Question.*—To construct the intersection of two cylindric surfaces, of any bases.

"*Solution.*—In making the research in which this question originates, if we have no other intersections to consider than that of the two cylindric surfaces, (and especially when these surfaces have circular bases) it will be found expedient so to choose the planes of projection, as that one among them may be parallel to the generating lines of the two cylinders: by which means the intersection will be constructed without the aid of any other curves than those given. But when we are obliged also to keep in view the intersections of these surfaces with others, there is no longer any advantage to be derived from a change of the planes of projection; it will even prove more easy to represent the objects by referring them all to the same planes. We shall therefore suppose the generating lines of the two surfaces to be placed indifferently as to the planes of projection.

"Under this idea, let T F U F′, X G V G′ (*Figure* 34) be the given horizontal traces of the two cylindric surfaces; A B, $a\ b$ the given projections of the right line, to which the generating line of the first is parallel; C D, $c\ d$, those of the line to which the generating line of the second is parallel. Suppose a series of planes parallel to the two generating lines: such planes will intersect the two surfaces in right lines; and the coincidences of the sections made in the first surface with those made in the second, will determine the points of the intersection required.

"Thus, after having constructed, as in *Figure* 15, the horizontal trace, A E, of a plane drawn along the first given right line, parallel to the second, draw as many parallel right lines, F G′, to this trace as you please, and consider such parallels as traces of the planes of the series. Each line, F G′, will cut the trace of the first surface in such points as F, F′, and that of the second in such as G, G′, through which draw to the respective projections of the generating lines, the parallels F H, F′ H′ . . . . . G J, G′ J′; and the intersecting points, P, Q, R, S, of these lines, will be the horizontal projections of so many points of the intersection of the two surfaces. By working in a similar manner on the remainder of the lines F G′, we shall obtain a succession of systems of points P, Q, R, S, and the curve that will pass through all the points so found, will be the horizontal projection of the intersection.

"To obtain the vertical projection, project upon L M the points F, F′ . . . . . G, G′ . . . . . in f, f . . . . . g, g' . . . . . and draw through these latter points, to the projections of the respective generating lines, the parallels $f'\ h, f'\ h$ . . . . $g\ i, g'\ i'$ . . . . and their coincidence will determine the vertical projections, p, q, r, s, of the points of intersection. And by thus proceeding with all the other lines F G′, we shall obtain new points p, q, r, s, and the curve that would pass through such points will be the vertical projection of the intersection.

"In order to obtain the tangents of these curves to the points P, p, construct the horizontal trace, F′ Y, of the plane tangent in this point to the first cylindric surface; then the trace, G′ Y, of the plane tangent in the same point to the second surface; and the right line drawn from the point P to the point Y of the coincidence of these traces, will be the tangent in P. Lastly, project Y upon L M in y, and draw the right line $p\ y$, and it will give the tangent to the point p of the vertical projection.

"*Eighth Question.*—To construct the intersection of two revolving surfaces, whose axes are in the same plane.

"*Solution.*—Dispose the planes of projection in such a manner, that one among them shall be perpendicular to the axis of one of the surfaces, and the other parallel to the two axes. Then let A, *Figure* 35, be the horizontal projection of the axis of the first surface; $a\ a'$ its vertical projection; and $c\ d\ e$ the given generating line of such surface. Let A B, parallel to L M, be the horizontal projection of the axis of the second surface; $a'\ b$ its vertical projection, so as that A, a' be the projections of the point of coincidence of the two axes; $f\ g\ h$ the given generator of the second surface. Conceive a series of spherical surfaces, whose common centre would be in the point of concourse of the two axes; and for each of such surfaces construct the projection $i\ k\ n\ o\ p\ q$ of the great circle parallel to the vertical plane of paojection; which projections, being arcs of circles described from the central point a', with radii taken arbitrarily, will cut the two generating lines in the points $k\ p$.

"We shall now find each spherical surface cutting the first surface in the circumference of a circle whose plane is perpendicular to the axis $a\,a'$, and whose vertical projection may be obtained by drawing the horizontal line $k\ o$, and its horizontal projection, by describing from the central point A, with a diameter equal to $k\ o$, the circumference of a circle K R O R'. In like manner, every spherical surface of the series will cut the second revolving surface in the circumference of a circle whose plane will be perpendicular to the vertical plane of projection, and whose vertical projection may be obtained by drawing through the point p a line, $p\ n$, perpendicular to $a'\ b$.

"Should the points r, in which the two right lines $k\ o, p\ n$, intersect each other, be nearer to the two respective axes than are the points $k\ p$, it is evident that the two circumferences of circles would intersect each other in two points, of which r would be the common vertical projection; and a curve drawn through all the points r, constructed in a similar way, would be the vertical projection of the intersection of the two surfaces. By projecting the point r upon the circumference of the circle N R O R', in R, R', we shall have the horizontal projection of the two points of the coincidence of the circumferences of circles found upon the same sphere; and the curve drawn through all the points R, R', constructed in like manner, will be the horizontal projection of the intersection required.

"These examples may suffice for conveying an idea of the method to be adopted in constructing the intersections of surfaces, and drawing tangents to them; more especially if the student be careful to make his constructions with scrupulous exactness, if he employ large dimensions, and, as much as possible, trace the curves in all their extent.

"In the foregoing pages, we have supposed the curves of double curvature as being each determined by two curved surfaces, of which it is the intersection; and, indeed, such is the point of view wherein they most commonly present themselves in descriptive geometry; and, under this consideration we have shown that it is always possible to draw tangents to them. But, although a curved surface may be defined by means of the form and movement of its generator; it may nevertheless happen, that a curve may be given, by the law of motion, from a generating point; in which case, if the practitioner do not choose to have recourse to analysis, he may adopt the method of Roberval. This method, invented by him before Descartes had applied geometry to algebra, is implicitly comprised in the processes of differential calculi, and is therefore not noticed in the elements of the mathematics; a summary exposition of it in this place, will be sufficient; those who are curious to see numerous applications of this method may consult the *Memoirs of the Academy of Sciences* (French) anterior to the year 1699, wherein the works of Roberval have been collected.

"When, pursuant to the law of its motion, a generating point is constantly impelled towards one particular point in space, the line it describes by virtue of such law is a right line; but if, in the whole course of its movement, it be at the same time impelled towards two points, it will in general describe a curve, though in particular cases it may describe a right line. The tangent to such curve may be obtained by drawing through the point of the curve two right lines, following the two different directions of the motion of the generating point; by measuring upon these directions, in an appropriate manner, parts proportional to the swiftness of two respective motions of the point; by completing the parallelogram, and drawing the diagonal, which will be the tangent required; for this diagonal will be in the direction of the movement of the describing point to the point of the curve under consideration.

"The following is an example.

"*Figure* 36.—A thread, A M B, being fastened by its extremities to two fixed points, A, B; if, by means of a point, M, this thread be stretched out, and the point moved, so as still to keep the thread in a state of tension, it will describe the curve D C M, being an ellipsis, whose foci are the fixed points A, B. From the generation of this curve, it is easy to draw a tangent to it, by Roberval's method. For instance; as the length of the thread is not altered, the radius A M, in every instant of its motion, is lengthened in the same proportion that the radius B M is shortened. The swiftness, therefore, of the describing point in the direction A M, is equal to its motion in the direction M Q. Therefore, by measuring on M B, and on the prolongation of A M, the equal right lines M Q, M P, and by completing the parallelogram M P R Q, the diagonal, M R, of this parallelogram will be the direction of the generating point in M, and consequently the tangent to the same point of the curve. Hence we may clearly perceive, that in the ellipsis, the tangent divides the angle B M P, formed by one of the vector radii, and by the prolongation of the other, in two equal parts; that, the angles A M S, B M R are equal to each other; and that the curve possesses the property of reflecting upon one of its foci the rays of light emanating from the other.

"The method of Roberval in the case of three dimensions, may be readily understood, and applied to the construction of tangents to curves of double curvature. Thus, if a generating point move in space, so as to be constantly impelled towards three different points, the line it will traverse, though in some particular cases it may be a right line, will in general describe a curve of double curvature. The tangent to such curve may be obtained in any point whatever, by drawing right lines from the given point, in the three directions of the movement of the generating point; by measuring upon such lines, in an appropriate direction, parts proportional to the swiftness of the three respective motions of this point; by completing the parallelopiped, and drawing the diagonal of the parallelopiped, which will be the tangent to the curve in the point taken.

"We shall now apply this method to a case analogous to that of the ellipsis. The *Figure* 37, to which we refer, represents the object in perspective and not in projection.

"Three fixed points, A, B, C, being given in space, let a thread, A M B, be fastened by its two extremities to the points A, B; let a second thread, A M C, independent in its size of that of the other, be attached by its extremities to the points A, C; let a generating point, holding both threads, be moved so as to keep them in a state of tension, and it will describe a curve of double curvature. In order to draw a tangent to this curve in the point M, we must observe that the length of the first thread, A M B, being uniform throughout its movement, the part A M is lengthened out precisely in proportion as the part M B is shortened, and that the swiftness of the generating point in the direction A M is equal to that of its movement in the direction M B. So, likewise, the length of the second thread, A M C, being unaltered, the swift ness of the generating point in the direction M C is equal to that of its motion in the direction A M. Therefore, by measuring upon the prolongation of A M, and on the right lines M B, M C, the equal parts M P, M Q, M R, and completing the parallelopiped M P U S V Q R T, we shall obtain in the diagonal, M S, of this parallelopiped, the tangent required.

"The method of Roberval being founded on the principle of compound motion, we may readily conceive that in cases more complex than these, which we have chosen as examples, we may avail ourselves of the known methods to find the resultance of forces impelled towards a point, whose size and directions are ascertained.

"*Application of the method of constructing the intersections of curved surfaces to the solution of various questions.*

"In *Figure* 26, we have defined the mode of constructing the projections of the intersection of two curved surfaces, definite in their form and position; which we have done in the abstract, that is, without attending to the nature of the questions whose solutions would require such operations. The exposition of this method, even in this abstract manner, will be found sufficient for most of the arts; for instance, in masonry and carpentry, the curved surfaces there considered, and the construction of whose intersections may be required, generally form the principal object of attention, and present themselves naturally. But as descriptive geometry will one day become a principal part of the national education, its methods being no less necessary to artists than reading, writing, and arithmetic; we conceive it must prove useful to point out, by a few examples, how it may furnish the analysis for the solution of a great number of questions, which, at first sight, seem not to admit of being treated in this manner. We shall begin with such examples as require only the intersections of planes, and then proceed to those in which the intersections of curved surfaces are necessary.

"The first question that forcibly occurs to those who are learning the elements of ordinary geometry, is the finding of the centre of a circle whose circumference passes through three arbitrary points on the plane. The determination of this centre by the intersection of two right lines, upon each of which it is necessarily found, surprises the pupil as well by its generality, as because it yields a mode of execution. Were all geometry treated in the same manner, which it may be, it would suit a much greater number of geniuses, would be cultivated and practised by a far more numerous class of men, the ordinary instruction of the nation would be more advanced, and the science itself carried to a greater extent.

"In the three dimensions, there exists a question analogous to the one just quoted, with which we shall begin.

"*First Question.*—To find the centre and radius of a sphere, whose surface passes through four points, given arbitrarily in space.

"*Solution.*—The four points being given by their horizontal and vertical projections, conceive right lines drawn from one of them to each of the others; and trace the horizontal and vertical projections of such lines. Then, in considering the first of these right lines, it will appear evident, that as the required centre must be at equal distances from the two extremities, it will be on the plane perpendicular to such right line, and drawn through its middle. Therefore by dividing the projections of the line into equal parts, which will give the projections of its middle, and by constructing the traces of the plane drawn through the point perpendicular to the line, as has been before described, we shall obtain the traces of a plane upon which the centre required will be found. Next, in considering the two other right lines, and working successively for each of them, a like operation, we shall obtain the traces of three several planes, upon each of which the centre sought for will be found. Now, as the centre must be upon both the first and second of these planes, it can be nowhere but in the line of their intersection, therefore, by constructing the projections of this intersection, we shall have upon each plane of projection, a line containing that of the centre. For the same reason, if the projections of the intersection of the first and third planes be constructed, we shall have on each plane of projection another line containing the projection of the centre. Hence we have upon each plane of projection two right lines, whose intersection will determine the projection of the required centre of the sphere.

"By using the intersection of the second and third planes, we shall obtain a third right line, that passes through the centre, and whose projections also pass through those required, which furnishes a means of verification.

"As to the radius, it is evident, that a right line drawn through the projection of the centre and that of one of the given points, will be its projection; whence we may obtain both the horizontal and vertical projections of the radius, and consequently its size.

"When the position of the planes of projection can be chosen at pleasure, the preceding method may be considerably simplified. Thus, suppose the plane that we have considered as horizontal (*Figure* 38) to pass through three given points, so as that of the given projections A, B, C, D, of the four points, the three first may be blended with their respective points; then, having drawn the three right lines, A B, A C, A D, suppose the vertical plane to be parallel to A D, that is to say, that the right lines L M and A D are parallel to each other; the vertical projections of the three first points will be upon L M, in such points as *a*, *b*, *c*, and that of the fourth will be given somewhere in a point, *d*, of the right line D *d*, perpendicular to L M. This done, the line drawn from the point A to B, being horizontal, any plane perpendicular to it will be vertical, having for its horizontal projection a line perpendicular to A B. It is the same with respect to the right line drawn from A to C. Therefore, by drawing through the middle of A B, the indefinite perpendicular E *e*, we shall have the horizontal projection of a vertical plane, that passes through the centre of the sphere; consequently, the horizontal projection of the centre will be somewhere on the line E *e*. So, likewise, by drawing through the middle of A C, the indefinite perpendicular F *f* we shall have the projection of a second vertical plane, that passes through the centre of the sphere, and the horizontal projection of this centre will be in some point of the right line F *f*: therefore, the point G, of the intersection of the two lines E *e*, F *f*, will be the horizontal projection of the centre of the sphere, and its vertical projection will consequently be upon the indefinite right line of projection G *g* *g'*.

"The line drawn from the point A to the fourth point being parallel to its vertical projection *a d*, any plane perpendicular to it, will also be perpendicular to the vertical plane of projection, and will have its vertical projection in a right line perpendicular to *a d*. Hence by drawing through the middle of *a d*, the indefinite perpendicular H *h*, we shall obtain the projection of a third plane, that passes through the centre of the sphere; therefore the vertical projection of the centre being at the same time upon *g g'* and H *h*, must be in the point K, of the intersection of these two lines.

"Lastly, by drawing the two right lines A G, *a* K, we shall evidently have the two projections of the same radius of the sphere; therefore, by measuring A G upon L M, from *g* to J, we shall have, in the right line J K, the size of the radius required.

"*Second Question.*—To inscribe a sphere in a given triangular pyramid; that is to say, to find the position of the centre of the sphere and the size of its radius.

"*Solution.*—As the surface of the inscribed sphere must touch the four faces of the pyramid, it is evident that a plane passing through the centre of the sphere and through each of six arêtes, would divide the angle formed by the two faces that pass through the same arête, into two equal parts. If, then, three of the six arêtes be chosen, which do not all pass through the same apex of a solid angle, and if through each of these arêtes a plane be made to pass, dividing in two equal parts the angle formed by the two corresponding faces, we shall obtain three planes, upon each of which the centre

of the sphere required will be found, whose position will be determined by their common intersection.

"In order to simplify the construction, we shall suppose the planes of projections to be so chosen as that the one which we consider as horizontal may be the same with one of the faces of the pyramid.

"*Figure* 39.—*Plate* 4. With this view, let A, B, C, D, be the given horizontal projections of the apices of four solid angles of the pyramid, and a, b, c, d', their vertical projections; conceive through the apex of the pyramid, planes perpendicular to the three sides of the base; such planes will be vertical, and their horizontal projections will be the right lines D E, D F, D G, falling perpendicularly from the point D on the sides A C, C B, B A, of the base. Each of these planes will cut the base of the pyramid and the face that passes through the arête in two right lines, comprehending between them an angle equal to that which the face forms with the base. Then, by measuring on L M the right lines D E, D F, D G, beginning from the vertical line D d d', from d to e, f, g, and drawing from the apex d', the right lines d' e, d, f, d' g, the latter will form with L M angles equal to those formed by the corresponding faces of the pyramid with the base; and if each of these three angles be divided into two equal parts by the right lines e e', $f f'$, g g', the angles formed by these last lines with L M, will be equal to those formed by the base with the faces of a second pyramid, having the same base with the given pyramid, and whose apex will be in the centre of the sphere required.

"To find the apex of this second pyramid, let it be cut by a horizontal plane, drawn at an arbitrary height, whose vertical projection may be obtained by drawing any horizontal line whatever, as p n. This line will cut e e', $f f'$, g g', in the points h', i', k', from which let the vertical lines h' h, i' i, k' k, fall upon L M; and by measuring the three distances h e, i f, k g, on the respective perpendiculars, from E to H, from F to J, and from G to K, we shall have in H, J, K, the horizontal projections of points taken in the three faces of the second pyramid, and which will be found upon the arbitrary horizontal plane. Then by drawing through the points H, J, K, to the respective sides of the base, parallel lines, as P N, N O, O P, they will be the projections of the sections of the three faces of the second pyramid, upon the same horizontal plane; they will also intersect each other in points, as N, O, P, which will be projections of as many points of the three arêtes of the second pyramid; and by drawing from these points to the apices of the respective angles of the base, indefinite right lines, as A P, B O, C N, such line will be the projections of the arêtes; lastly, the single point Q, wherein they all three meet, will be the horizontal projection of the apex of the second pyramid, and consequently of the centre of the sphere required.

"To obtain the vertical projection of this centre, draw, first, the indefinite right line of projection Q q q', on which it will be found; then project the three points, N, O, P, on the horizontal line n, p, in n, o, p; draw through the projections, a, b, c, of the apices of the respective angles of the base, the right lines a p, b o, c n, and they will be the vertical projections of the three arêtes; and the single point, q', wherein the three last lines cut each other, and which will be at the same time on the right line Q q q', which will be vertical projection of the centre of the sphere.

"Lastly, the vertical line q q' will be evidently equal to the radius of the inscribed sphere, and the points Q, q, will be the projections of the point of contact of the surface of the sphere with the plane of the base.

"We have shown by what considerations we are enabled to determine the position of a point, after having ascertained its distances from three points of known position; we shall now proceed to the actual construction of this question.

"*Third Question.*—To construct the projection of a point, whose distances from three other points given in space is known.

"*Solution.*—*Figure* 40. Let the planes of projection be so chosen as that the one considered as horizontal may pass along the three given points, and let the other be perpendicular to the right line by which two of the points are joined. Then let A, B, C, represent the three given points; and A′, B′, C′, their given distances from the point required. Join two of the points by the right line A B, perpendicularly to which draw L M, and it will determine the position of the vertical plane of the projection. Take the points A, B, C, as centres, and describe with radii equal to the respective distances A′, B′, C′, three arcs of circles, which may cut each other by two's, in the points D, E, F, J, P, Q; through the intersecting points of these arcs taken by two's, draw the lines D E, F J, P Q, and they will be the horizontal projections of the circumferences of circles wherein the three spheres intersect each other; and the single point N, wherein these three lines meet, will evidently be the horizontal projection of the point required.

"In order to obtain the vertical projection of the same point, draw the indefinite line of projection N n n'; then, observing that the circle projected in D E is parallel to the vertical plane, and that its projection on this plane must be a circle of equal radius, project the line A B upon L M, in the point r, from which, as a centre, and with an interval equal to D R, or the half of D E, describe the circle d n e n', and the circumference will cut the right line N n n', in two points, n n', which will be indifferently the vertical projection of the point required.

"According to the other circumstances of the question, we may determine whether the two points n, n', ought to be both used; and in case of one only being necessary, which of them to prefer, and which to reject.

"*The reader may propose to himself the construction of the projections of a point whose distances from three lines given in space are known.*

"*Fourth Question.*—An engineer, when surveying a mountainous country, whether for the purpose of studying the form of the earth, or for making a draught for public works dependent on such form, is furnished with a topographical chart, whereon not only the projections of the different points of the earth are exactly laid down, but also the altitudes of all these points above a level surface, are indicated by figures placed on their sides respectively, commonly called *quotas*: he meets with a remarkable point, not placed on the chart, either in consequence of an omission, or because it has become remarkable since the chart was drawn. The engineer has no instrument of observation about him, except a graphometer, used for measuring angles, furnished with a plumb-line.

"Placed in such circumstances, he is required, without quitting the station, to construct on the chart the position of the point in question, and to find the suitable quota, *viz.* its height above the level surface.

"*Mode of Solution.*—Among the points correctly described on the chart, nearest to the one under consideration, let the engineer select three, of which two at least are not of the same altitude with that on which he stands; then let him observe the angles formed by the zenith with the visual rays directed to these three points, and by this single observation he may resolve the question.

"For instance: Let A, B, C, represent the three points observed, whose horizontal projections are on the chart, and whose vertical projections he may construct, by means of

their quotas. Knowing the angle formed by the zenith with the visual ray directed to the point A, he is also acquainted with the angle formed by the same ray with the vertical line raised above the point A: for, disregarding the convexity of the earth, which is here admissible, these two angles will be found to be alternate-internal, and consequently equal. Then by conceiving a conic surface, of a circular base, with its apex in the point A, its axis vertical, and forming with its axis and generating line an angle equal to the angle observed, which completely determines such surface, it will pass along the visual ray directed to the point A, and consequently along the point of the station: thus he will have a first curved surface determined, on which he may find the point required. By proceeding in a similar manner for the points B, C, as for the first, the point required will farther appear on two other conic surfaces, with circular bases, having their axes vertical, their apices in the points B, C, and each forming an angle with its axis and generating line equal to the angle formed by the zenith and the corresponding visual ray. The point sought for, therefore, will be at the same time upon three conic surfaces, of determinate forms and positions, and consequently in their common intersection. It remains then only to construct, according to the data of the question, the horizontal and vertical projections of the intersections of these three surfaces, taken by two's; the intersections of these projections will give the horizontal and vertical projections of the point required, and consequently its position on the chart, with its height above or below the points of observation, which will determine the quota.

"This solution will generally produce eight points in answer to the question; but the observer may readily distinguish among them that which coincides with the point of the station. He may at first sight ascertain whether the point of the station be above or below the plane that passes along the three points of observation. Suppose this point to be above the plane of the apices of the cones; he may then neglect such branches of the intersections of the conic surfaces as are below the plane, which will reduce the number of possible points to four. So, on the contrary, were the point of the station placed below the plane, the number of points would be equally reduced by omitting such branches as were above it. Then among these four points, if indeed so many exist, he will easily recognize that whose position, relatively to the three apices, is the same with that of the point of the station, relatively to the points of observation.

"*Construction.—Figure* 41. Let A, B, C, represent the horizontal projections of three points of observation taken on the chart; *a*, *b*, *c*, the vertical projections of such points, constructed by measuring on the vertical lines B *b*, C *c*, beginning from the horizontal line L M, passing through the point *a*, the difference of the quotas of the two other points; and let A′ B′ C′, represent the angles which the visual rays, directed to the respective points A, B, C, form with the zenith.

"Draw the indefinite vertical lines *a a′*, *b b′*, *c c′*, and they will be the vertical projections of the axes of the three cones; through the three points *a*, *b*, *c*, draw the right lines *a l*, *b m*, *c n*, and they will form with the vertical lines, angles respectively equal to the given angles A′, B′, C′; which right lines will be each the vertical projection of one of the two extreme sides of the corresponding conic surface.

"This done, draw in the vertical projection horizontal lines, *e e′* at pleasure, which may be considered as the projections of as many horizontal planes, and for each of them work the operation we are about to describe for the one indicated by E E′.

"This line will cut the projections of the axes of the three cones in points *f*, *g*, *h*, that are the vertical projections of the centres of the circles, according to which the corresponding horizontal plane cuts the three conic surfaces; it will also cut the extreme sides of the cones *a l*, *b m*, *c n*, in such points *f′*, *g′*, *h′*, that the distances *f′ f g g′ h h′*, will be the radii of these circles. From the points A, B, C, taken successively as centres, and with the radii respectively equal to *f f*, *g g′*, *h h′*, describe circles, whose circumferences will be the horizontal projections of the sections made in the three conic surfaces by the same plane E E′; these circumferences will intersect each other, two by two, in points D D′, K, K′, J, J′, that are the projections of as many points of the three intersections of the conic surfaces, considered by two's; and by projecting these points upon E E′, *d d′*, *k k′*, *i i′*, we shall obtain the vertical projections of the same points of the three intersections.

"By afterwards working in the same manner upon the other right lines *e e′* we shall obtain from each of them new points, D, D′, K, K′, J, J′, in the horizontal projection, and likewise *d*, *d′*, *k*, *k′*, *i*, *i′*, in the vertical one; then pass a curve, D P D′, through all the points D, D′.... and it will be the horizontal projection of the intersection of the first conic surface with the second; pass another curve, K P K′, through all the points K, K′.... and it will be the projection of the intersection of the second surface with the third: and by passing a third curve, J P J′, through all the points J, J′...., we shall have the projection of the intersection of the third surface with the first. All the points P.... wherein these three curves intersect each other, are the horizontal projections of as many points answering to the question.

"So, in the vertical projection, by passing a first curve through all the points *d*, *d′*.... a second through all the points *k*, *k′*.... and a third through all the points *i*, *i′*.... we shall have in such curves the vertical projections of the intersections of the three surfaces, taken in pairs; and all the points, *p*.... wherein such curves intersect each other, will be the vertical projections of all the points necessary to the solution of the question.

"The projections P, *p*, of an identical point will be in the same perpendicular to L M.

"Having discovered among the points P the one indicative of the point of the station, the observer will be in possession of the horizontal projection of such station, and, consequently, of its position on the chart; then by means of the altitude of the corresponding point *p* above the right line L M, he may obtain the elevation of the point of the station above that of the point of observation A., and that will give him the appropriate quota.

"In this solution we have constructed the projections of the three intersections of the surfaces; but two would have been sufficient. Yet we would always advise the adoption of this practice, because the projections of the two curves of double curvature may intersect each other in points not correspondent to those of intersection; and also, because in order to recognize the projections of the points of intersection, it is necessary to follow the branches of the two curves that are upon the same face of one of the surfaces; which requires a laborious degree of attention, seldom, if ever, necessary in constructing the three curves: the points wherein they all three cut each other, are true points of intersection.

"*Fifth Question.*—Under circumstances similar to the preceding, except that the instrument is not furnished with a plumb-line, so that the angles formed with the zenith cannot be measured, the engineer is required, without quitting the station, to determine on the chart the situation of the point where he is, and to find the quota belonging to it, viz. its elevation above the level surface to which all the points of the chart refer.

"*Mode of Solution.*—Having made choice of three poin

of land, whose situations are accurately marked on the chart, and of such kind as not to be in the same plane with the point of the station, let the engineer measure the three angles which he visual rays directed towards those three points form with each other; and by means of this simple observation he will be able to resolve the question.

"Thus, by letting A, B, C, represent the three points of observation, and supposing them to be joined by the right lines A B, B C, C A, the engineer will be in possession of the horizontal projections of such lines, traced on the chart; and by means of the quotas of the three points, he may obtain the differences of the altitudes of the extremities of the lines; he may, therefore, ascertain the size of each of them.

"This done, if any plane whatever, drawn through A B, a rectangular triangle, B A D (*Figure* 42) be conceived as constructed, with A B for its base, whose angle in B is the complement of the angle under which the side A B has been observed, the angle in D will be equal to the angle of obser vation, and the circumference of a circle described through the points A, B, D, will possess the property that if from any point whatever, E, of the arc A D B, two right lines be drawn to the points A, B, the angle, in E, which they include, will be equal to the angle of observation. If, then, the plane of the circle be conceived to turn upon A B, as on a hinge, the arc A D B will generate a revolving surface, all whose points will be endowed with the same property, viz. that if from any point of the surface two right lines be drawn to the points A, B, they will include an angle equal to the angle of observation. Now, it is evident that the points of such revolving surface alone possess this property; therefore the surface passes through the point of the station.

"By operating in a similar manner upon the two other lines B C, C A, two other revolving surfaces will be obtained, on each of which the point of the station will be found; this point will therefore be at the same time upon three different revolving surfaces, determined as to their form and position; consequently it must be a point of their common intersection. Thus, in the construction of the horizontal and vertical projections of the intersections of these three surfaces, taken in pairs, the points in which the three projections cut each other will be the projections of the point answering the question. The horizontal projection will be its position on the chart, and the vertical projection its elevation above or below the points of observation.

"Were this question to be treated by analysis, it would generally lead to an equation of the sixty-fourth degree; for each of the revolving surfaces has four distinct faces, two of which are generated by the arc A D B, and the other two by the arc A F B. As each of the faces of the first surface may be cut by all those of the second, sixteen branches may be the result in the curve of intersection; and as these may be again cut by the four faces of the third surface, they may produce sixty-four points of intersection in the three surfaces; though they would not all apply to the solution of the question. Thus, if from any point, as F, of the arc A F B, lines be drawn to the extremities of A B, the angle A F B, included by them, would not be equal to the angle of observation, but would be its supplement. The faces generated by the arc A F B, and the analogous faces in the other revolving surfaces, cannot therefore serve towards the solution of the question; and all the intersecting points belonging to any of these faces are foreign to the problem.

"In descriptive geometry, we may, and indeed should exclude the arc A F B, and those analogous to it, in the two other surfaces; each of which will then have but two faces, and the number of their possible points of intersection will be reduced to eight. Of these, four will be on one side of the plane passing through the three revolving axes, and four on the other. The observer, being always aware of the side on which he is placed relatively to this plane, will, of course, not construct the intersections of the opposite side, so that the number of points will in fact be reduced to four. Now, among these four points, if they all exist, he will readily know which is placed in respect to the points A, B, C, in a manner similar to that of the station relatively to the three points of the country that he has observed.

"*Construction.*—Select the position of the two planes of projection so as that the one taken as horizontal may pass through the three points observed, and that the other may be perpendicular to the right line drawn through two of those points. Let then A B C (*Figure* 42) represent the triangle formed by the points observed, considered in its plane, and A′, B′, C′, the three angles given by the observation. Draw perpendicularly to the sides A B, the right line L M, which will indicate the position of the vertical plane of projection; and construct, according to the directions already given, the generating arcs A E D B, B G C, C F A, of three revolving surfaces, whose sides, A B, B C, A C, are the axes. Then, taking the point A as a centre, describe arcs of circles, as E O F, at pleasure, and they will cut the generators, whose axes meet in A, in such points as E, F, from which, drop upon the respective axes, the indefinite perpendiculars E E′, F F′; these perpendiculars will intersect each other somewhere in a point, as H, which will be the horizontal projection of a point of intersection of the two surfaces, whose axes are A B, A C; and the curve, A H P, drawn through all the points H.... thus found, will be the horizontal projection of this intersection. Next, after projecting the axis A B in *a*, take the point *a* as a centre, and describe from it, with radii successively equal to the perpendiculars E E′, arcs of circles, as *e e′ h*, on each of which, by projecting the point H, to its corresponding point in *h*, we shall have the vertical projection of a point of the intersection of the two same revolving surfaces; and the curve, *a h p*, drawn through all the points, *h*.... so constructed, will be the vertical projection of this intersection.

"The same method may be pursued for the two surfaces revolving about the axes A B, B C; *viz.* taking the point of coincidence, B, of the two axes as a centre, describe arcs of circles, as D K G, at pleasure; which arcs will cut the two generators in points, as D, G, from which drop on the respective axes the indefinite perpendiculars D, D′, G G′; these perpendiculars will cut each other in a point, as J; and the curve, B J P, drawn through all the points J... will be the horizontal projection of the intersection of the first and third revolving surfaces. Taking the point *a* as a centre, with radii successively equal to the perpendiculars D D′, describe arcs of circles, as *d d′ i*, on which project in *i* the corresponding points J; and the curve, *a i p*, drawn through all the points *i*, will be the vertical projection of the same intersection.

"Here we shall find that all the points, P.... in which the two curves A H P, B J P, cut each other, are horizontal projections of so many points applicable to the question; and that all the points, *p*.... in which the curves *a h p*, *a i p*, intersect each other, are the vertical projections of the same points.

"The projections, thus found, will not give immediately the position of the point of station on the chart; nor its height, because the horizontal plane is not that of the chart; but it will be easy to find them on the true planes of projection.

"*Sixth Question.*—The general of an army meets that of an enemy, but not having a chart of the country, is at a loss how to form his plan of attack. But being in possession of

a balloon, he dismisses an engineer in it, to make the necessary arrangements for constructing a chart, and to give as near an idea of the level of the country as possible. Fearing, however, that, should the balloon be suffered to change its station over the earth, the enemy might anticipate his design and frustrate it, he permits the engineer to raise himself to different altitudes in the atmosphere, if necessary, but not to alter his perpendicular station. The engineer is provided with an instrument for the measurement of angles, which is also furnished with a plumb-line: it is asked, how can the engineer fulfil the object of his general?

"*Solution.*—The engineer must take two stations in the same vertical line, whose difference he may ascertain by measuring the cord let out, to raise the balloon from one station to the other. In one of these, the lowest, for example, let him measure the angles made by the zenith with the visual rays directed towards the points whose position he wishes to determine on the chart; then, among these points, let him select one, which he will consider as the first, and which we shall denominate A; let him also measure successively the angles formed by the visual ray directed to the point A, and those directed towards all the other points. In the second station, let him measure the angles formed by the zenith with the visual rays directed to all the points of the country: and from these observations, he may construct the chart required.

"When we are acquainted with the angles formed by the zenith with the two visual rays directed from the two stations towards the same point, we know that such point is at once upon two determinate and known conic surfaces, with circular bases, having their axes in the same zenith, the distance of their apices equal to the difference of the altitudes of the two stations, and the angles formed by their generators with the common axis equal to the angles observed. Also, when we are acquainted with the angle formed by the visual ray directed from the first station to this point, and by that directed towards the point A, we know that the point considered must likewise be on a third conic surface, with a circular base, whose inclined axis is the visual ray directed from the first station towards the point A, having its apex in the first station, and forming an angle between its axis and generator equal to the angle observed. The point considered, therefore, will be found at the same time on conic surfaces with circular bases, of known form and position; consequently it must be the point of their common intersection; and by constructing the horizontal and vertical projections of the intersection, we shall obtain the position of the point on the chart, with its elevation above or below others.

"Without varying from these considerations, the construction may be rendered more simple, by some of the methods already prescribed: for with a knowledge of the angles formed at the first station by the visual ray directed towards the point A, and by the rays directed towards all the other points; and knowing the angles formed by the sides of these angles with the zenith, it is easy to reduce them to the horizon, viz. by constructing their horizontal projections. By selecting, therefore, on the chart, an arbitrary point, to represent the projection of the zenith of the balloon, and drawing an arbitrary right line through it, to represent the projection of the visual ray directed towards A; drawing also, through the same point, right lines, making with such projection of the ray, angles equal to those reduced to the horizon; it is evident that each of these lines must contain the horizontal projection of its correspondent point of country. It only remains, then, to find the distance of this point of the country from the zenith. For this purpose, take, in the vertical projection, and upon the projection of the zenith of the balloon, two points, which in parts of the scale are distant from each other equal to the measured distance of the two stations, and through these points draw right lines making with the zenith angles equal to those observed for an identical point of country; which lines will cross each other in a point whose distance from the zenith will be the distance required; and by measuring it on the corresponding ray, beginning from the projection of the balloon, we shall have on the chart, the position of the point of country. The same two right lines, in the vertical projection, will, by their intersection, determine the height of such point; therefore, by taking on the vertical projection, the heights of all the points of country above a common horizontal plane, we shall be able to determine the quotas suitable for all the points of the chart, and likewise the level of the country.

"This construction is so easy, that it does not require a figure.

"The right line drawn from the projection of the zenith of the balloon to that of the first point, A, observed, having been in the first instance traced upon the chart arbitrarily, it follows that the chart is not adjusted to the cardinal points, and, indeed, in the observations laid down, we find nothing by which to determine the objects observed towards them. But if an engineer observe on the earth, the angle made by the meridian with a visual ray directed from the foot of the zenith towards one of the points placed on the chart, and if he describe this angle upon its projection, he will have the direction of the meridian, and the chart will be adjusted to the cardinal points."

The great length to which our extracts from Monge's work have extended, will be, we trust, pardoned, in consideration of the value of those extracts; and of our desire to do the most ample justice to the learned and ingenious author. Though many works of a similar kind by eminent writers have since issued from the press, the *Geometrie Descriptive* of Monge still holds a most distinguished place; and will continue to be regarded as one of the best elementary books of modern times.

DESICCATION, (Latin, *desicco*, to dry), the act of making dry; it is the chemical operation of drying bodies and is effected in different modes, according to the nature of the substance. The term, Desiccating Process, has been applied to a patented invention, (Davison and Symington's Patent), for seasoning or drying a great variety of substances. It is said to have been used with success in seasoning wood.

DESIGN, (*designo*, Latin; *dessein*, French), an original drawing of a building to be executed, comprehending the invention, composition, and arrangement of the whole. A design includes plans, elevations, and sections of the building intended to be carried into execution, besides other drawings of *details*, or *parts at large*. The number of these will, of course, depend either upon the nature of the building, that is, on its being more or less complex, or as it is intended to show it more or less fully. A small simple house will only require one plan and an elevation. A large edifice, with great variety of parts, will require plans of each story, elevations of the different fronts, a longitudinal and transverse section, and, in general, as many drawings as will be sufficient to explain all the parts All the minute parts, as bases, capitals, architraves, friezes, cornices, and other mouldings, are to be exhibited in their true geometrical proportion, at full size.

There is, perhaps, a certain prejudice against drawings of this kind, from an impression too generally entertained, that they are unintelligible except to the initiated. This feeling would be easily removed, were unprofessional persons to take the pains to examine a complete set of well-prepared architectural drawings. A very little explanation renders these draw

ings perfectly clear to any person of common capacity, however ignorant he may be of architecture.

To begin with the *plan.*—This may be described as the *map* of the building. By its means we distinguish most clearly the exact shape and extent of the structure as regards the space on which it stands; the thickness of the walls, the internal arrangement of all the rooms and passages; and the situation and width of doors, windows, fireplaces, staircases, &c. The raised and solid parts, such as walls, columns, piers, &c., are shaded; the voids and apertures, such as doors, windows, &c., are left white. For every story of a building there should be a separate plan, although it is not usual, in books of designs, to give more than those of the ground-floor, and the principal one above it.

Next to the plan we may describe the *Elevation.* This may be defined as a vertical plan; it shows the front, or one external face of the building, and gives the precise forms and measurements of every part, drawn to scale. It must be observed, that the particular in which an elevation differs from other drawings, and from the appearance of the objects themselves, is, that no distinction is made between curved horizontal lines and straight ones; so that, whether the part be a plane or a curved surface, can be understood only from the shadowing, unless there happens to be something that assists in denoting curvature of plan. Thus, the mouldings of the base of a column are all straight lines; consequently, without shadow to express rotundity, we could not determine whether they belonged to a flat or a round surface, unless the shaft be fluted, in which case the flutes will diminish in width, according to their distance from the centre.

Elevations have sometimes given to them something of a pictorial character, by colouring as well as by shadowing, and not unfrequently by the addition of sky and background. It would be better, perhaps, were such accompaniment restricted to what may be just sufficient to relieve the building, instead of being extended over the whole picture, and carefully worked up; because such additions to the usual plain architectural drawing are calculated to give a formal and stiff appearance to the drawing, offensive to good taste and simplicity. In modern architectural publications, especially foreign ones, *outline* elevations are now generally given; these are preferable to those which are shadowed, as they exhibit all the forms more distinctly, and admit of being measured with much greater exactness.

We next proceed to describe the *Section.* A section is the projection or geometrical representation of a building supposed to be cut by a vertical plane, for the purpose of exhibiting the interior, and describing the height, breadth, thickness, and manner of construction of the walls, &c. By the section we are made acquainted with a variety of particulars, in regard to which a plan cannot be made to afford any information. It shows us the thickness of the walls and floors, the heights of the rooms, the forms and profiles of ceilings, whether flat, coved, or arched, also the exact forms of domes and skylights. It shows the heights of the doors, how they are panelled and decorated, the form of the chimney-pieces, &c., and, in some instances, furniture and fittings-up are advantageously introduced, with a view to judge of effect. For detailed and filled up sections, it is usual to employ outline with the walls and floors shaded, the former as more solid, being made darker than the latter. When, on the other hand, the elevations of the rooms themselves are shadowed, the thickness of the intersected walls, &c., are left white, in order to prevent confusion, and exhibit the profiles better.

Indispensable and interesting, however, as they are, sections are a far more conventional mode of drawing than elevations, because they represent a building as it never can be seen, except where the front of a house has been taken down for the purpose of rebuilding it, while the floors and partition-walls are left standing; in which case any one may obtain a good idea of the nature of a section, but of one seen in perspective.

Besides general sections showing the whole of a building from top to bottom, there are frequently partial ones, showing only the rooms on one floor, or even a single room, when it is desired to show any particular apartment on a larger scale than could conveniently be done any other way. Sometimes recourse is had to a plan of the room with each of its sides drawn around it, as if laid flat on the ground, by which means the whole of the apartment is described. Horizontal sections also are given, to show more accurately than can be done on a plan, the soffits of entablatures, the ceiling and its ornaments, the window recesses, and door-cases, and the capitals of columns and projection.

Besides the usual plans, elevations, and sections, there should also be detailed drawings, answering, in some respect, to what are termed *working drawings;* these give a more correct idea of the minutiæ and finishing of the subject than can be obtained from the general design only.

In a complete design, however, it is desirable to have perspective views both of the exterior and principal parts of the interior. These enable a person to comprehend the character and effect of the design as a whole, which, without such drawings, can be judged of only piecemeal. The perspective drawing of the exterior ought to exhibit the edifice from one of the most frequented points of view, and ought also to be so contrived as to make it impressive from every point whence it can be seen, and particularly from those positions in which the greatest part of the design is comprehended at one view.

In very large works, a model will be useful for preventing many mistakes that might otherwise arise, as all the parts can be easily seen by inspection; but when drawings only are used, from the number that are necessary to the performance of the work, a long examination and consideration are requisite; and after all, some of the most essential parts of the construction may be, and frequently are, overlooked.

For other particulars respecting designs, we refer to the articles Apartment, Break, Building, House.

DESIGNING, the art of delineating or drawing the appearance of natural objects by lines on a plane.

DESK, a part of a pulpit; as the clerk's or precentor's *desk;* also a kind of rostrum where the clergyman reads the printed service of the English Church.

DESTINA, Latin, a pillar or other support of a building, in which sense the term is used by Vitruvius; but when employed by ecclesiastical writers, it is usually applied by them to the aisle of a church, or to a small cell.

DETACHED COLUMN, the same as Insulated Column, which see.

DETAIL, (from the French, *détailler*) the delineation of all the parts of an edifice, so as to be sufficiently intelligible for the execution of the work. The detail is otherwise denominated *the working drawings.*

The expression *detail* is also used in other ways, as, when a moulding is exhibited in profile by abutting on a plane, it is said to *detail* on the plane. Details in the fine arts are minute and particular parts of a picture, statue, or building, as distinguished from the general conception, or larger parts of a composition.

DETERIORATION, (from the Latin, *deterior*) the act whereby a thing is rendered worse. This was the fate of architecture in passing from the Greeks to the Romans, and more particularly in the decline of the Roman empire.

DETERMINATE, a word applied in mathematics to those problems which have one answer only, or at least a certain and finite number of answers.

DETERMINING LINE, in conic sections, the intersection of a plane parallel to the cutting plane with the plane of the base of the cone. In the sections of a cone which produce the hyperbola, the determining line falls within the base of the cone; in parabolic sections, it forms a tangent to the base. In the elliptic section, it falls without; and when the section is a circle, the determining line will, in one case, never meet the plane of the base, as in this instance the cutting plane is parallel to the plane of the base.

DIACONICON, (from *διακονεω*, *I serve*, *I minister*) a place adjoining to the ancient churches, where the sacred vestments, vessels, relics, and ornaments of the altar, were preserved. This apartment was otherwise called *sacristy*. It was also denominated *ασπ ςικον*, and in Latin, *salutatorium*; because it was here that the bishop received and saluted strangers. Sometimes it was called *μητατωνιον*, or *μιτατωριον*, *mensa*, on account of the tables kept there.

DIAGONAL, (from the Greek, *διαγώνιος*) in geometry, a line drawn through any figure, from the vertex of one angle to that of another.

Every rectilinear figure may be divided into as many triangles, wanting two, as the figure has sides.

Every diagonal divides a parallelogram into two equal parts.

A most excellent theorem in elementary geometry, first demonstrated by Mr. Lagny, in the *Mémoires de l'Academie Royale des Sciences, an.* 1706, is, that the sum of the squares of the two diagonals of every parallelogram is equal to the sum of the squares of the four sides; and it is evident that the 47th proposition of Euclid may be derived as a mere corollary from this theorem. The demonstration is as follows: Let A B C D be an oblique parallelogram, of which B D is the greater diagonal, and A C the lesser. From the vertex, A, of the obtuse angle D A B, drop the perpendiculars A E and B F to C D; then the triangles A D E, B C F, are equal and similar; for A D is equal to B C, and the angles A D E and B C F are equal to each other; also the angles A E D, and B F C, are equal to each other; consequently D E is equal to C F. Now, by proposition xii. lib. ii. of Euclid, in the obtuse-angled triangle B D C, the square of the side B D is equal to the sum of the squares B C, C D, together with double the rectangle C F by C D; and by the 13th proposition of the same book, in the triangle D A C, the square of A C is equal to the sum of the squares of A D and C D, abating double the rectangle of C D by D E equal to C F; for C F is equal to D E: now, since

$$\begin{aligned} BD^2 &= BC^2 + CD^2 + 2(CF \times CD) \\ \text{and } AC^2 &= AD^2 + AB^2 - 2(CF \times CD) \end{aligned}$$

$$\text{Therefore } BD^2 + AC^2 = BC^2 + CD^2 + AD^2 + AB^2$$

Then, if the parallelogram be right-angled, the diagonals are equal, and consequently each equal to the squares of the two sides containing other right angles opposite that diagonal.

Hence, if one of the diagonals and a side be known, the other diagonal will likewise be known.

Another proposition, of a similar nature to the above, was discovered by Ptolemy, viz., that the rectangles of any two diagonals of a quadrilateral figure inscribed in a circle, is equal to the sum of the two rectangles contained by the opposite sides.

In taking the dimensions of a building, in order to make a plan, it is by far the most accurate and expeditious method, to take the diagonals. In carpentry and joinery, no polygonal frame whatever can be rendered stationary or immovable about the angles, without diagonal pieces, as the strength consists in dividing the work into triangles. In geometry, a polygon cannot be constructed by the linear dimensions of its sides only, without the diagonals, as the area of the figure may be variable under the same number of sides, *ad infinitum*, from a certain position of the sides, in which they will contain the greatest possible area to any less area whatever.

The impulse given to a body, at the same instant, by two forces, in different directions, causes that body to move in the diagonal of a parallelogram, of which, each of the forces acting separately, would cause the body to describe a side, in the same time as the body moved conjointly by the two forces.

DIAGONAL BUTTRESS, a buttress placed at the angle of a building, chiefly used in churches of mediæval date, and employed to resist the thrusts of the ribs of the last severy of the vaulting. It answers the same purpose as two distinct buttresses set square with the two walls at their intersection, but with less material. Diagonal buttresses do not seem to have been employed to any extent previous to the fourteenth century, but are common in buildings of the Decorated style. Previously, two buttresses at right angles were employed.

DIAGONAL MOULDING, the same as ZIG-ZAG or DANCETTE.

DIAGONAL PAVING. *See* PAVEMENT.

DIAGONAL RIB, a rib or groin passing diagonally across a bay of vaulting from one angle to the opposite.

DIAGONAL SCALE, a compound scale, by which a subdivision may be made of any part of the smallest unit upon a straight line, by means of equidistant parallels crossing others of the same kind.

DIAGRAM, (from *διαγραφω*, *I describe*) in geometry, a scheme for the explanation or demonstration of a figure.

DIAL, (from the Latin, *dies*, day) an instrument serving to measure time by the shadow of the sun. Or more particularly, the surface of a body so graduated that a certain line parallel to the earth's axis will show the hour of the day, when the sun shines upon the surface of such body.

DIAMETER, (from *δια*, *through*, and *μετρειν*, *to measure*) a straight line passing through the centre of a circle, and terminated at each end by the circumference; the diameter is therefore a chord passing through the centre of the circle, and is consequently greater than any other chord in the same circle.

The diameter of a circle divides the circumference into two equal parts.

For other particulars, see the article CIRCLE.

DIAMETER OF A COLUMN, the thickness of the lowest part of the shaft at the bottom. In a colonnade, or range of columns, the intercolumns should always be proportioned to the diameter of the column.

DIAMETER OF A CONIC SECTION. *See* CONIC SECTION.

DIAMETER, *Conjugate*. *See* CONIC SECTION.

DIAMETER OF DIMINUTION, the diameter at the top of the shaft.

DIAMETER OF A SPHERE. *See* SPHERE.

DIAMETER, *Transverse*, the longest axis of an ellipsis.

DIAMETERS, *Conjugate*, of a circle, two diameters at right angles.

DIAMOND, an instrument for cutting glass.

DIAMOND, the small instrument used by glaziers for cutting glass, and formed by the setting of a fractured piece of diamond in a wooden handle. There are now in use two descriptions of pencil diamonds, the old one, and the new or patent pencil. The defect of the former is the difficulty experienced in placing it on the glass in, at once, the proper angle, so as to make it cut and not scratch. The patent

pencil overcomes this difficulty, the diamond being fixed by the peculiar mode of its setting at the correct angle at which it will cut the glass. The diamond in these pencils is about the size of an ordinary pin's head, and is set in a nipple of brass or copper. They are differently fitted up, according to the quality of the material which they are to work upon.

DIAMOND FRET, a species of moulding consisting of fillets intersecting each other, so as to form diamonds or rhombuses.

DIAMOND, *Glass*. *See* GLASS.

DIAMOND, *Pavement*. *See* PAVEMENT.

DIANA, *Temple of*. *See* TEMPLE.

DIAPER, a panel or recessed surface enriched with carving in low relief, and frequently gilded and coloured; or a plain surface enriched with polychrome. Also a kind of linen-cloth wrought with figures in weaving.

DIAPERING, the decoration employed in the relief of any plain surface by the interweaving of fret-work, or covering the field with ornamental patterns. In some cases, it consists in the application of colour only, but in others of embossed or carved work, delicately chiselled, and also enriched with gilding and colour. Diaper-work is usually composed of small square panels, containing flowers in low relief, as in the spandrels of the choir arches, and in other parts of Westminster Abbey. There is a beautiful specimen of later date on a monument in the choir of Canterbury cathedral; the design is composed of a flower of six leaves in low relief, within a sexagonal compartment, the sides of which are formed by the sides of six spherical triangles, and are foliated within, and coloured azure and gules. Another specimen is to be seen in the Lady Chapel, Ely, at the back of the canopies of the ornamental arcade which surrounds the walls; others at Waltham Cross, and in many buildings erected during the reigns of Henry III. and Edward I. Diaperings of a rich and tasteful design were also employed in ecclesiastical hangings, vestments, &c. Some very beautiful designs may be seen in *Pugin's Glossary*.

DIASTYLE, (from δια, and ϛυλος, *a pillar*) in classical architecture, that distance between columns equal to three diameters of the column; or the word is applied to the edifice itself, in which columns are applied at this interval.

DIATHYRA, the vestibule in front of the doors of a Greek house, answering to the prothyra of the Romans.

DIATONI, quoins or corner-stones bonding two walls together.

DIDORON, (from the Greek) a kind of brick used by the Greeks, being one foot long and half a foot broad.

DIE, of a pedestal, that part contained between the base and the cornice. *See* DYE.

DIFFERENTIAL, a term used to denote an infinitely small quantity. The differential method is applied to the doctrine of infinitesimals; it consists in descending from whole quantities to their infinitely small differences, and comparing them. Hence it is called the differential calculus or analysis of infinitesimals.

DIGGING is performed by the solid yard of 27 cubic feet.

In soft ground, where only cutting with the spade is necessary, a man will throw up a cubic yard in an hour, or 10 cubic yards in a day. But if hacking be necessary, an additional man will be required; and very strong gravel will require two. The rates of a cubic yard depending thus upon each circumstance, they will be in the ratio of the arithmetical numbers 1, 2, 3. If, therefore, the wages of a labourer be 2s. 6d. per day, the price of a yard will be 3d. for cutting only; 6d. for cutting and hacking; and 9d. when two hackers are necessary.

In sandy ground, when wheeling is requisite, three men will be required to remove 30 cubic yards a day, to the distance of 20 yards, two filling and one wheeling; but to remove the same quantity in a day, to any greater distance, an additional man will be required for every twenty yards.

To find the price of removing any number of cubic yards to any given distance:

Divide the distance in yards by 20, which gives the number of wheelers; add the two cutters to the quotient, and you will have the whole number employed; multiply the sum by the daily wages of a labourer, and the produce will be the price of 30 cubic yards.—Then,

As 30 cubic yards is to the whole number, so is the price of 30 cubic yards to the cost of the whole.

Example.—What will it cost to remove 2,750 cubic yards, to the distance of 120 yards, a man's wages being three shillings per day?

2,0)12,0
————
6 number of wheelers.
2 fillers.
——
8 men employed.
3 shillings per day.
——
24 price of 30 cubic yards.

$$30 : 2750 : : 24 : \frac{2750 \times 24}{30} = £110.$$

See farther under EXCAVATION.

DIGLYPH, (from the Greek, διγλυφος), a tablet with two engravings or channels.

DIKE, or DYKE, (from the Saxon, *dic*, a bank or mound), a work of stone, timber, or earth, supported by fascines, raised to oppose the entrance or passage of waters of the sea, a river, lake, or the like. These dykes usually consist of elevations of earth, strengthened with hurdles or stakes, stones, and other matters.

DILAPIDATION, (from the Latin), the state of a building suffered to fall into a ruinous condition by neglect. The term is usually restricted, in its legal sense, to the pulling down or destroying the houses or buildings belonging to an ecclesiastical benefice, or suffering them by neglect to fall into ruin or decay. In the experience of every-day life, there are few families who have not had occasion to feel how much of annoyance, inconvenience, and loss may be hidden under the word *dilapidations*.

In the "Builder" of January, 1849, there appeared an excellent letter on this subject, and as it is evidently written by one well acquainted with it, we consider its insertion here will be both interesting and useful:—

"This subject," says the writer, "is one that has never received proper consideration from the hands of a large class who are interested and affected by it—'tenants.' Men who are daily imposing upon themselves heavy responsibilities, the extent, or the peculiar obligations, and the ultimate result of which they are totally unacquainted with.

"Few persons on taking a lease think of raising objections to covenants which are, they are informed, of the usual character; or, if prudent enough to pledge themselves to an agreement of but three years, they fearlessly, and without hesitation, affix their signatures to a clause promising to 'uphold, maintain, and sustain' &c., or that which really may turn out an impossibility; for some houses, so to speak, have the elements of destruction and disease upon them from

their infancy. Bad brickwork, causing by its humidity damp walls, rots everything; unseasoned timber, that shrinks and twists in all directions, throwing floors out of their level, and making settlements from top to bottom, through which the doors and windows have to be constantly eased and rehung; faulty and imperfect drainage, which becomes constantly choked; the roof acting like a sieve; and this list of ills that modern houses are heir to, is no exaggeration; yet many a man, and he, too, who may be esteemed in his own business a prudent man, is induced, from a want of consideration, readily to promise to do and perform all needful and necessary repairs, or at least to leave the house in tenantable repair. It is not a little amusing to observe the tenant's surprise at the end of his tenancy, on receiving a notice of dilapidations. What! he exclaims, and leave the house 100 per cent. better than when I took it? This, and the various sums of money paid to jobbing tradesmen, all the accounts of whom he can enumerate by heart, constitute the anchor of hope to the poor tenant, when informed, in spite of all the benefits the house has derived from him during his tenancy, that still such and such are dilapidations, and as such he is answerable for their being reinstated. In the present age, remarkable for the number of scantily-constructed houses, with so nice and clean, yet deceitful, an exterior, invitingly waiting for tenants on lease or agreement, it cannot fail to be useful to consider the nature of the obligation that exists between landlord and tenant upon the hire of house-property; for as mistakes will happen in the best regulated families, so do the friendship and good understanding that may have existed between landlord and tenant suddenly cease with the termination of the lease. Covenants to repair, when once entered into, are irrevocable; it is, therefore, most important that each party should clearly understand what constitutes repairs or dilapidations; and as to all defects, whether they arise from accident, neglect, or decay, and by which party they are to be made good.

"A landlord, on making a claim from his tenant for dilapidations, must show that they are such as were stipulated for in the lease, as the obligation on the part of the tenant to make good, varies, in nearly every case, according to the different covenants of the lease, by which the tenants are bound by more or less stringent clauses, involving greater or less responsibilities.

"Mr. Gibbons, in an excellent treatise on this subject, defines dilapidations as the act or default of a person having to use a tenement to the injury of another having a right to the same tenement, or a tenant's obligation may be considered as depending on the old maxim—'You must not injure another's property, but use it as your own.'

"It is an imperative act of justice to himself for the future tenant to make a stipulation that, previous to the commencement of his tenancy, the premises shall be surveyed; so that, if then there can be considered anything unsound or defective on the premises, it may be made good before the agreement is concluded, otherwise the tenant will find that he must make good all, whatever was the state of repair when he took possession of the premises.

"*Houses held on lease.*—In the case of premises being let on lease, as tenant should not be compelled to supply and make good defects that may arise from time and use, because, as the tenant bargained for use, and gives to the owner an equivalent rent, the landlord has a claim only for a restoration of the tenement as injured by the tenant, but has no right to make a claim for the wear to be made good; but then, as the tenant agrees to keep the house in tenantable repair, he is bound to supply all occasional and accidental defects which may expose the premises to premature decay. Accidents happening during his tenancy, if not inevitable, must be made good by the tenant, for it is fair to presume, that had he adopted proper precautions, the accident might have been prevented; therefore, there exists an obligation not to suffer dilapidations, and it is evident that the tenant is equally bound not to do any act that will cause an injury to the tenement.

"*Voluntary waste* means an alteration in the tenement, it being held in law that a lessee cannot change the nature of the thing demised; the act of alteration exceeds the right to use, and infringes on the condition that the landlord shall receive back the premises in the same state and condition as when the lease was granted. It is, therefore, essential that a tenant contemplating an alteration or improvement should receive proper permission and authority from the landlord."

"*Permissive waste* consists of a neglect on the part of a tenant to supply the repairs required by time and use, and also a neglect to make good occasional and accidental dilapidations. Houses and outbuildings are the principal subject of dilapidations, but the law extends to trees, land, changing the course of industry, &c., but the chief subject is buildings. These, though subject to decay in the progress of time, are capable of having the defective or decayed parts made good, and are therefore subject to both permissive and voluntary waste.

"A tenant hiring premises on lease is bound to perform tenantable repairs, which may be divided into three heads,—the ornamental, which includes the trades of painter and paper-hanger; the substantial, which includes the trades of bricklayer and carpenter; the third includes all works which tend to preserve the fabric from decay—as, stopping out wind and weather, which includes the trades of the joiner, plasterer, and glazier.

"Dilapidations caused by accident are very serious upon a tenant, as not only is the accident considered as a dilapidation, but injuries arising therefrom, of which the following is an illustration from Mr. Gibbons:—'If a building be covered with weather-boarding, and such boarding decay from age, so long as it form an entire and complete covering, it is no dilapidation; but if, owing to any neglect, any of the internal woodwork become injured, that is a dilapidation. If the main timbers decay, they are not chargeable as a dilapidation, so long as they are an efficient support; but if they give way, the tenant is bound not only to replace the timbers, but all damage done by their fall. Accident, shown to be inevitable, such as resulting from tempests, does not fall upon the tenant, as in the case of a house being prostrated, the tenant need not rebuild, but if the roof be blown off, the tenant must replace it. A tenant, generally speaking, is *not* answerable for dilapidations resulting from natural decay, or the result of time, or fair ordinary wear and tear, but *is* answerable for all extraordinary decay. For instance, as to decay, caused by the premises being exposed to the weather, as if the roof be suffered to go in bad repair, the tenant must make good the rafters and other timbers, if they are injured.' Lord Chief Justice Tindal defined a tenant's obligation to repair thus:—'Where an old building is let, and the tenant enters into a covenant to repair, it is not meant that the old building is to be restored in a renewed form at the expiration of his tenancy, or that the premises shall be of greater value than it was at the commencement. What the natural operation of time flowing on effects, and all that the elements bring about in diminishing the value, which, so far as it results from time and nature, constitute a loss, falls upon the landlord. But then the tenant must be careful that the tenement do not suffer more than time and nature would effect. He is bound to keep the premises in nearly the same state of repair as when demised.'

"*An annual tenant's* obligation has been thus laid down by Lord Kenyon :—'A tenant from year to year is bound to commit no waste, and to make from time to time fair and tenantable repairs, such as windows and doors that be injured during the tenancy.' Lord Tenterden decided that 'an annual tenant was bound to keep the premises wind and water tight.'

"It seems but justice, that under any mode of letting or hiring of house property, a tenant should be bound to use all ordinary precautions to preserve the building from decay; therefore there exists an obligation to keep the outside and the roof sound, perfect, and water-tight; and if the internal woodwork decay sooner than it otherwise would do for want of paint, &c., the tenant is bound to restore it. Glass, if cracked or broken, becomes dilapidation, it being an outside covering.

"*A tenant with no agreement as to duration of his tenancy*, cannot be bound to perform any repairs, the nature of his tenancy being so weak that he cannot be expected to do any repairs, as his landlord might immediately determine his tenancy, and reap the advantage to be derived from the outlay : besides, if the house require any repairs being done, the landlord can enter, and take any necessary steps for its preservation; but not so with premises let for a definite time,—then, the landlord having granted the use for a certain period, has not a right to enter upon the premises until the expiration of the tenancy. A tenant under this mode of letting, is however bound neither to commit nor permit waste. This kind of tenancy may be considered rather as a 'deposit than as a letting on hire,' and the tenant's obligation may be defined as 'to use the house with care.'"

The above extract gives a very clear and concise description of the responsibilities undertaken by tenants under varied forms of tenancy. It is well worthy the attentive perusal of the young professional man, and indeed the whole subject of dilapidations is an important one, requiring his careful study. It is one on which he is very frequently called upon to advise; and he will scarcely be competent to do so unless well acquainted with the just claims of the landlord, and the fair obligations of the tenant. To give in a list of repairs required to be done, is simple enough in acting for the landlord, but the surveyor should be well assured, from a practical acquaintance with what really are dilapidations, to what extent he is justified in calling on the tenant to do them.

DIMENSION (from the Latin) a principal distance measured in a straight line on the surface of a body, in some particular direction, or through some certain point, by the help of which the body may be constructed or measured as to its superficial or solid contents.

The dimensions of rectangular figures and solids are taken along, or parallel to the straight lines which bound their surfaces; and consequently rectangles have two dimensions, viz. length and breadth, and rectangular prisms three dimensions, viz. length, breadth, and thickness. The dimension of a parallelogram are the length of one side, and the distance from that side to the opposite side of the same, so that the two dimensions of a parallelogram are at right angles to each other. The dimensions of any plane figure are the lengths of the sides and diagonals. The dimensions of a circle are its radius, diameter, or circumference, or all. The dimensions of a regular polygon are the length of one of its sides, and their number. The dimensions of any prism are the dimensions of one of its ends or bases, and the perpendicular or distance between the said ends or bases. The dimensions of a pyramid are the dimensions of its base, and the distance or perpendicular form the apex to the plane of the base. The dimensions of a sphere are its diameter or circumference. The dimensions of a spheroid are the fixed and revolving axes. The dimensions of an irregular surface or body are in a great measure arbitrary. The dimensions of an irregular surface are thus taken : Fix upon some principal line passing through the middle of the body in the direction of its greatest extension, as nearly as can be judged; then divide the length of this line into equal parts; through the points of division, draw perpendiculars, terminated by the boundary; then the length of the first line and of the perpendiculars are the dimensions. The dimensions of a definite body may be limited as to number, and the body may be accurately ascertained, either with regard to its construction or solidity; but an indefinite body can never be ascertained for either, whatever may be the number of its dimensions : greater accuracy, however, will be obtained, the greater the number of dimensions taken. The dimensions of an irregular plane figure or solid, ought to be taken in equidistant lines or planes.

The subjects to which dimensions are applied belong to geometry, mensuration, and the construction of solids. The method of squaring dimensions will be found under the articles CROSS MULTIPLICATION, DECIMALS, and DUODECIMALS.

In writing the dimensions of a body, consisting of many different parts, in order to avoid mistakes, an eye-draught, or sketch of the body, should be made, and two angles, each with its apex fixed in the opposite extremities of the extension, with a number placed between them to denote the length of the line: thus, $\langle$ - - - - - 36 ft. - - - - - $\rangle$ denotes 36 feet between the point of one angle and that of the other: the opening of each angle is always turned towards the centre of the line. By this method no mistake can occur, even though ever so many other dimensions cross one another, unless they come so close as to confuse. Simple rectangles, or rectangular prisms, are most frequently written down without any eye-draught, and the dimensions entered in the book with a cross between each, or the word BY; thus, for a rectangle, 3 . . 9′×4 . . 8′, or 3 . . 9′ by 4 . . 8′; that is, 3 feet 9 inches by 4 feet 8 inches; the mark thus′, signifying that the figures below are inches, and consequently that the first is the place of feet. A solid is thus denoted, 5 . . 3′ × 4 . . 8′ × 12 . . 6′, or 5 . . 3′ by 4 . . 8′ by 12 . . 6′; that is, the end, or base, is 5 feet 3 inches by 4 feet 8 inches, and 12 feet 6 inches from end to end; or the solid is 12 feet 6 inches long, 5 feet 3 inches broad, and 4 feet 8 inches thick.

In finding the contents of artificers' works in buildings, the dimensions are placed one under the other, according to their denominations, and the surface or solid is known by the number of its dimensions; in order therefore to distinguish any set of dimensions from the next, whether above or below, a horizontal line must be drawn between them. *See* the article BRICKWORK.

DIMENSION BOOK, a book in which the measurement of the builder's work is entered, specimens of which are given under the head BRICKWORK.

DIMINISHED BAR, of a sash, one that is thinner on the inner edge, or the edge next to the apartment, than where it recedes close to the glass, in order to give it a lighter appearance.

DIMINISHED COLUMN, one whose upper diameter is less than the lower; as is to be seen in all the regular orders of architecture.

DIMINISHING RULE, a board cut with a concave edge, so as to ascertain the swell of a column, and try its curvature. For the method of forming a diminishing rule, *see* COLUMN.

DIMINISHING SCALE, a scale of gradation, used in finding the different points for drawing the spiral curve of the Ionic volute, by describing the arc of a circle through every three

succeeding points, the extreme point of the last arc being one of the next three; each point through which the curve passes being so regulated as to be in a line drawn to the centre of the volute, and the lines at equal angles with each other. *See* SPIRAL and VOLUTE.

DIMINUTION OF COLUMNS, the continued contraction of the diameter from the base to the top of the shaft.

Some modern authors make the diminution to commence from one-third of the height of the column; but if ancient methods are to have a preference, we shall find few examples to authorize this practice. In all the Grecian antiquities of Athens, or Ionia, the diminution commences invariably from the bottom of the shaft, immediately above the apophyge: and, according to the engravings from Stewart's drawings, the diminution is continued in a straight line, excepting in the Temple of Corinth, where the swell is shown. The diminution is rarely less than one-eighth, or greater than one-sixth, of the inferior diameter.

In Gothic architecture, neither swell nor diminution is used; all the horizontal sections being similar and equal.

In ancient examples, even of the same order, the diminution is very variable.

Other particular remarks will be found under COLUMN.

DINING-ROOM, an apartment in a house, appropriated to the eating of dinners. The dining-room and drawing-room ought to have some relation to each other in point of size, as the company move from one to the other. In the smallest houses, the dining-room ought to be the largest, and nearly square upon a plan. In houses of a middle size, they are very frequently of the same magnitude, which may be 18 feet in breadth, 24 feet in length, and $13\frac{1}{2}$ feet in height, or 3-4ths of the breadth. In larger houses, the length may be extended to 40 feet; and in very considerable edifices even to 50 feet: in the latter case the length may be double the breadth.

Dining-rooms are sometimes fitted up with a recess at one end for receiving the side-board; but if the apartment be very large, a recess at each end is necessary: these recesses may be either square, or in the form of a niche. *See* HOUSE, *and* ROOM.

DINOCRATES, an eminent architect, patronized by Alexander the Great; whose history is thus related by Vitruvius:—"At the time that Alexander was conquering the world, Dinocrates, the architect, confiding in his knowledge and genius, and being desirous of obtaining the royal commendation, left Macedon, and repaired to the army. He carried with him letters from his relations and friends in his own country, to the nobles of the first rank, that he might thereby more easily gain access. Being favourably received, he requested to be immediately presented to Alexander; they gave him many promises, but made delays, pretending to wait till a proper opportunity should offer. Dinocrates, therefore, suspecting that he was derided, sought the remedy from himself. He was very large of stature, had an agreeable countenance, and a dignity in his form and deportment. Trusting to these gifts of nature, he clothed himself in the habit of a host, anointed his body with oil, crowned his head with boughs of poplar, put a lion's skin over his left shoulder, and holding one of the claws in his right hand, approached the tribunal where the king was administering justice. The novelty of the appearance attracting the notice of the people, occasioned Alexander also to see him, who, wondering at the sight, commanded way to be given, that he might approach. Alexander then demanded who he was. Dinocrates replied, 'I am a Macedonian architect, who come to thee with ideas and designs, worthy of the greatness of thy fame; I have formed a design to cut Mount Athos into the statue of a man, in whose left hand shall be a large city, and in his right a bason, which shall receive all the rivers of the mountain, and again discharge them to the sea.' Alexander, delighted with the idea, immediately inquired, if the country adjacent would produce sufficient food for the sustenance of the inhabitants. When he understood that provision must be conveyed thither by sea, he replied: 'Dinocrates, I discern the excellence of thy design, and am pleased with it; but I consider, that whoever should establish a colony in such a place, would hereafter be justly blamed; for, as a new-born infant cannot be nourished, or gradually reared to the different stages of life, without the milk of the nurse; so neither can a city be peopled, nor can it thrive, without fertile land and plenty of provision; however, as I approve the design, though I disapprove the place, I will have thee attend me, that elsewhere I may employ thee.' From that time, Dinocrates remained with the king, and attended him into Egypt. There Alexander, observing a spot which had a haven formed secure by nature, an excellent place for an emporium, the adjacent country through all Egypt being fruitful, and having the accommodation of the river Nile, ordered him to build the city now called, from his name, Alexandria. Thus, by the means of a graceful countenance and dignity of person, Dinocrates became eminent."

Dinocrates was also employed to superintend the rebuilding of the temple of Diana, at Ephesus, when burnt by Erostratus, which he did with more magnificence than before. The last design which history ascribes to him, was that of erecting a temple to Arsinoë, queen of Ptolemy Philadelphus, at Alexandria, with a dome above it, which was to enclose a magnet, in order to keep suspended in the air an iron statue of that queen. Ptolemy approved the design, and gave orders for its execution; but both the king and the architect died before the project could be accomplished.

DIOPHANTINE PROBLEMS, in mathematics, certain questions relating to square and cube numbers, and right-angled triangles, &c., the nature of which was determined by Diophantus.

DIOPHANTUS, a celebrated mathematician of Alexandria, reputed to have been the inventor of algebra. The exact date of his birth is unknown; some authors asserting that he lived before Christ, and others after, in the reigns of Nero and the Antonines. His reputation was very high among the ancients, since they ranked him with Pythagoras and Euclid in mathematical learning.

Diophantus left behind him thirteen books of arithmetical questions, of which, however, only six are extant.

DIORAMA, a mode of painting and scenic exhibition invented a few years ago by two French artists, Daguerre and Bouton. The peculiar, and almost magical effect of the diorama arises, in a great degree, from the contrivance employed in exhibiting the painting, which is viewed through a large opening or proscenium. Within this proscenium the picture is placed at such a distance, that the light is thrown upon it, at a proper angle from the roof, which is glazed with ground glass, and cannot be seen by the spectators. While the light is thus concentrated on the picture, the spectators are left in comparative darkness, by which the effect is materially increased; and the illusion is rendered still more complete, by the skilful manner in which the transitions of light are managed. The light may be diminished or increased at pleasure, and that either gradually or suddenly, so as to represent the change from ordinary daylight to sunshine, from sunshine to cloudy weather, or to the obscurity of twilight, and also the difference of atmospheric tone attending them. By means of different folds or shutters attached to the glazed

ceiling, transitions are produced in regard to light and atmospheric effects of the most pleasing character. The diorama is indeed a most perfect scenic representation of nature; by varied and ingenious contrivances, it is capable of displaying the greatest difference in its pictures. It is peculiarly adapted for moonlight subjects, and for exhibiting such "*accidents*" in landscapes as sudden gleams of sunshine and their disappearance. For showing architecture, particularly interiors, it is unrivalled, as powerful relief may be obtained without that exaggeration in the shadows which is almost inevitable in every other mode of painting. Although as yet only employed for purposes of public exhibition, the diorama might undoubtedly be made use of for the embellishment of such parts of a building as corridors and the like, where light can only be obtained from one extremity.

The Diorama in the Regent's Park, was erected for the exhibition of pictures with the effects we have been describing; and as one of the most interesting and remarkable of the "sights in London," deserves a passing notice.

The pictures exhibited are each about 72 feet long, and 42 feet wide, and are capable of being shifted and exchanged for others when required. They are placed at distances from the spectator proportioned to the angle at which he would view the object in nature; and by the united talents of the artist and the machinist, the illusion is rendered so perfect, and so true to nature, that the beholder is almost led to doubt that they are really the effect of art. Thus, in architectural subjects, as the interior of the cathedral, the whole is at one moment subdued by gloom, as by the overshadowing of some passing cloud. The "long-drawn aisle" and deep recesses are obscured, all seems about to be buried in darkness, when, in an instant, as though the interruption had passed away, and the bright light of day was permitted to shine through the windows in its full lustre, the Gothic architecture is illumined in the most beautiful manner, the shadows projected with force and truth, and the secondary lights produced beneath the groinings of the roof in all the delicate gradations of natural reflections. Landscape scenes undergo similar changes, and admirable effects are produced in the transitions from shade and darkness, to the brightness of light and sunshine.

The elevation of the building was designed by Mr. Nash; it is of the Ionic order, the basement embellished with columns and pilasters, &c., the centre of which is the approach to the theatre. The building consists of a vestibule and two lateral houses, facing a circular part of the edifice, which may be regarded as the audience-room of the theatre, and is occupied by boxes, and an open area for spectators. The sides of this circular part are painted and adorned with festooned draperies, and the top is covered with a transparent painting, divided into many compartments, and charged with medallion likenesses of several eminent artists. Over this semi-transparent ceiling, or inner roof, rises a conical roof, nearly half of which is glazed. The circular part consists of a wall, two-thirds of a circle, with two small doorways, and two large openings to the compartments of the scenic theatre. Immediately within this wall, but detached from it, is another wall, rising from the floor to the inner ceiling, and which, with the floor, revolves on a pivot beneath. A large square opening, like the proscenium of a theatre, allows the audience to view the pictures.

The Diorama was opened to the public in October, 1823, and has ever since continued to be visited as one of the most popular exhibitions in the metropolis.

DIPTERON, or DIPTEROS, (from the Greek), or DIPTERE, (from the French), in ancient architecture, a temple surrounded with a double row of columns, forming a sort of porticos, called *wings*, or *aisles*. Vitruvius informs us, that dipteral temples were octostyle; but this he must mean only in general; for they may be also decastyle. Indeed, they could not have been less than octostyle, as no room would have been left for the cell. The same author also observes, that Hermoginus made a very great improvement in the construction of dipteral temples, by taking away the interior range of columns, which occasioned confusion in the perspective appearance.

DIRECT RADIAL, a right line from the eye, perpendicular to the picture.

DIRECTING LINE, the line in which an original plane would cut the directing plane.

DIRECTING PLANE, a plane passing through the point of sight, or the eye, parallel to the picture.

DIRECTING POINT, that in which any original line produced cuts the directing plane.

DIRECTOR OF AN ORIGINAL LINE, the straight line passing through the directing point and the eye of the spectator.

DIRECTOR OF THE EYE, the intersection of the plane with the directing plane, perpendicular to the original plane and that of the picture, and hence also perpendicular to the directing and vanishing planes; since each of the two latter is parallel to each of the two former. The director of the eye is also sometimes called *the eye director*.

DIRECTRIX, or DIRIGENT, in geometry, a term expressing the line of motion along which a describent line, or surface, is carried in the genesis of any plane or solid.

Thus, if the line A B move parallel to itself, and along the line A C, so that the point A always keeps upon the line A C, it will form a parallelogram, A B C D, of which the side A B is the describent, and A C the dirigent. So, also, if the surface A B C D be supposed to be carried along the line C E in a position always parallel to itself, in its first situation, the solid A D E H will be formed, when the surface A D is the describent, and the line C E is the dirigent.

DIRETTA, the same as GOLA, or SIMA-RECTA, which see.

DISCHARGE, (from the French), a term applied to a brick wall, or post, when trimmed up to a piece of timber overcharged in its bearing; in which case the wall or post is a discharge to that bearing.

DISCHARGING ARCHES, rough brick or stone arches, built over the wooden lintels of apertures. These are scheme arches, being the segments of very large circles. Discharging arches are employed in the inside of external walls or in partition walls. The length of the chord of a discharging arch should exceed that of the wooden lintels beneath, so that when the wood begins to decay, the lintels may be taken out, and the arch will be sufficient to sustain the superincumbent part of the wall, as well as that the arch may be sustained by the walls, and not have any dependence upon the lintels. To make the arches resist with greater force, the lintels should not have more wall-hold than what may be found sufficient to sustain the superincumbent part while building: indeed, if walls be well built, upon firm ground, wooden lintels may be dispensed with.

DISCHARGING STRUTS, the same as *auxiliary rafter*, or *principal braces*: the term is used by Batty Langley.

DISH-OUT, to form coves by any kind by means of ribs, or to form wooden vaults for plastering upon.

DISHING-OUT, any kind of coved work formed by wooden ribs, for plastering upon. The term is of the same import as *cradling*.

DISPLUVINATED CAVÆDIUM. *See* CAVÆDIUM.

DISPOSITION, (from *dispono*, to place), in architecture, the just placing of the several parts of a building, according

to their use; as, disposition of apartments, disposition of columns, as eustyle, diastyle, pichnostyle, &c.

DISTANCE OF THE EYE, in perspective:—If a straight line be drawn from the eye, perpendicular to the plane of the picture, the intercepted part of such line is termed *the distance of the eye.*

DISTANCE, *Point of.* See POINT OF DISTANCE.

DISTANCE OF A VANISHING LINE, the length of a perpendicular, falling from the eye perpendicular to the vanishing line.

DISTANCE, *Inaccessible.* See TRIGONOMETRY.

DISTEMPER, (from the French, *détremper*, to temper or dilute,) in painting, the working up of colours with something besides mere water or oil. If colours be prepared with water, the painting is called *liming;* and if with oil, it is called *painting in oil*, or simply *painting.*

If the colours be mixed with size, whites of eggs, or any such proper glutinous or unctuous substance, and not with oil, they then say it is done *in distemper;* as those of the admirable cartoons, formerly at Hampton Court, and as all ancient pictures are said to have been before the year 1410.

In distemper, the white colour or base generally used is the finest whiting, which is prepared in large quantities by various manufacturers. The colours most commonly mixed with it for producing the various tints are as follows:—Straw colour may be made with white and masticot, or Dutch pink; fine grays, with white and refiner's verditer; an inferior gray may be compounded with blue black or bone black, and damp blue or indigo; pea-greens, with French green, Olympian green; and fawn colour, with burnt sienna or burnt umber and white, and so of any intermediate tint. All the colours used in distemper, should either be ground very fine, or washed over so as to ensure the most minute division of their particles. In general, the size made of common glue is used with a proper quantity of water to render the colour liquid, but where the work will afford it, parchment-size will be found greatly superior.

It will not require less than two coats of any of the foregoing colours, in order to cover the plaster, and bear out with an uniform appearance. When old plastering has become discoloured with stains, and it be desired to have it painted in distemper, it is advisable to give the old plaster, when properly cleaned off and prepared, one coat at least of white-lead ground in oil, and used with spirits of turpentine, which will generally cover all old stains, and, when quite dry, will take the water-colours very kindly.

The best methods of compounding the colours with the vehicles, is to mix the size in water, then to levigate the colours in part of it, and afterwards to put each kind into a proper pot, adding as much more of the melted size as will bring it to a due consistence, and mixing the whole well together in a pot with a brush or wooden spatula. Warm water may be afterwards added, if necessary, for grinding the colours, or for working. The pots must be covered with bladders, and tied. This method of painting is chiefly confined to scenes and grosser works, where the effect depends more upon the perspective and opposition of the colours, than upon their brightness.

DISTRIBUTION, the dividing and disposing of the several parts of a building according to some plan, or to the rules of architecture. The proper distribution or arrangement of the various apartments in a large building is of great importance, and may be either good or bad, as they may be best suited to answer their use. That arrangement only can deserve the former appellation, in which every apartment seems placed in its very best position, with regard to architectural symmetry, elegance of appearance, and domestic convenience.

DISTYLE, (Greek, δυω-στυλος), a portico of two columns. It applies rather to a portico with two columns in antis, than to the mere two-columned porch.

DITRIGLYPH, an interval admitting two triglyphs over the intercolumn; that is, if in two adjoining columns a triglyph be placed with its middle over each, the ditriglyph will contain three metopes, or spaces, two half triglyphs, and two whole triglyphs.

DIVAN, among the Orientals, a council-chamber, or the saloon or hall in which a council is held: it is applied generally to denote a state apartment, or room in which company is received.

DIVERGING LINES, such as are continually increasing in their distance from each other.

DIVIDERS. See MATHEMATICAL INSTRUMENTS.

DIVISION, *Harmonical.* See HARMONICAL DIVISION.

DIVISION OF AN ORDER. See ORDER.

DOCK, an artificial receptacle for shipping, generally formed by excavation, and enclosed by gates, which open for the ingress and egress of vessels; the sides are usually constructed of masonry.

DOCK, a place artificially formed on the side of a harbour or bank of a river, for the reception of ships. Docks are of two kinds, wet-docks and dry-docks. A wet-dock is an excavation or basin, of considerable extent, which vessels can enter to discharge or take in their cargoes, and in which they are always afloat; of this kind are the immense docks of London, Liverpool, and other places of great commerce. A dry-dock is used for inspecting and repairing ships, and is so contrived, that the water can be admitted or excluded at pleasure, so that a vessel can be floated in when the tide is up, and the water may run out with the fall of the tide; or, the gates of the dock being closed to prevent the egress of the water, it is pumped out by steam-power. Dockyards belonging to the government usually consist of dry-docks for repairing ships, and of *slips* on which new vessels are built; besides which they comprise storehouses, in which various kinds of naval stores are kept, and workshops in which different processes subsidiary to ship-building, are carried on.

DODECAGON, (δωδεκα, *twelve* and γωνια, *angle*), a regular polygon or figure, with twelve equal sides and angles.

If the radius of a circle O A D F, be so divided into two parts, that the rectangle under the whole and the one part shall be equal to the square of the other part; then this last part will be equal to the side C D of a regular decagon A B C D E F, &c., inscribed in the circle; and that line whose square is equal to the two squares of the whole, and of the same part, will be equal to the side, A C, of a regular pentagon inscribed in the same circle. For, draw the radii O A, O C, O D, O F; also draw A D, cutting O C in G, and let A H be perpendicular to O G. The triangle O D G, having the angle $COD\ (=\frac{1}{2}DOF = OAD) = ODA$, is isosceles: the triangle A O G, having $AGO\ (= GDO + DOG = 2\,DOC) = AOC$, is likewise isosceles; as is also the triangle C D G; because, C G D being $= AGO$, and $CDG\ (CDA) = FAD$, the triangles A O G and C D G are equiangular; consequently, C D, A O; C G, G O, being corresponding sides, we have $CG \times AO\ (CG \times CO) = CD \times GO = GO^2$, because $GO = GD = DC$, the side of the decagon, &c. Moreover, because $AG = AO$, HG will be $= HO$; and G C being the difference of the segments H O and H C, we have $AC^2 - AO^2 = CO \times GC = OG^2$; and consequently AC^2 (*i. e.* the square of the side of the pentagon) $= AO^2 + OG^2$.

Let $CO = a$, $GO = x$, then will $CG = a - x$; and by

this proposition $\overline{a - x} \times a = x^2$ and $x^2 + a\,x = a^2$; and resolving this quadratic equation, we shall have $x^2 + a\,x + \frac{1}{4} a^2 = a^2 + \frac{1}{4} a^2 = \frac{5}{4} a^2$; whence $x + \frac{1}{2}\,a = \sqrt{\frac{5}{4}\,a^2}$, and $x = \sqrt{\frac{5}{4}\,a^2} - \frac{1}{2}\,a$. Let the radius a be $= 1$, and G O, or the side of a regular decagon inscribed in the circle, is $= \sqrt{\frac{5}{4}} - \frac{1}{2}$. Hence it appears that the sine of 18^{0} (or half the side of a decagon inscribed in the circle) is $= \frac{1}{2}\sqrt{\frac{5}{4}} - \frac{1}{4} = \frac{1}{2}\sqrt{1.25} - \frac{1}{4} = \frac{1.11803398}{2}$, &c. $- \frac{1}{4} = .55901699$, &c. $- .25 = .30901699$, &c.

If the side of a dodecagon be 1, its area will be equal to three times the tangent of $75^{0} = 3 \times 2 + \sqrt{3} = 11.1961524$ nearly; and, the areas of plane figures being as the squares of their sides, 11.1961524 multiplied by the square of the side of any dodecagon, will give its area. Hutton's *Mensuration*, p. 114.

To inscribe a dodecagon in a given circle.—Carry the radius six times round the circumference, which will divide it into six equal parts, or form a hexagon, (See HEXAGON); then bisect each of those parts, which will divide the whole into 12 parts, for the dodecagon.

DODECAHEDRON, (from δωδεκα, *twelve*, and ἑδρα, *seat*,) one of the regular bodies comprehended under twelve equal sides, each of which is a pentagon; or, a dodecahedron may be conceived to consist of twelve quinquangular pyramids, whose vertices, or tops, meet in the centre of a sphere conceived to circumscribe the solid; consequently they have their bases and altitudes equal.

To find the solidity of the dodecahedron.—Find that of one of the pyramids, and multiply it by the number of bases, viz., 12; the product is the solidity of the whole body. Or its solidity is found by multiplying the base into one-third of its distance from the centre, twelve times; and to find this distance, take the distance of two parallel faces; the half is the height.

The diameter of the sphere being given, the side of the dodecahedron is found by this theorem; the square of the diameter of the sphere is equal to the rectangle under the aggregate of the sides of a dodecahedron and hexahedron inscribed in the same, and triple the side of the dodecahedron.

Thus, if the diameter of the sphere be 1, the side of the dodecahedron, inscribed, will be $(\sqrt{\frac{5}{3}} - \sqrt{\frac{1}{3}}) \div 2$; consequently, that is to this as 2 to $(\sqrt{\frac{5}{3}} - \sqrt{\frac{1}{3}})$ and the square of that, to the square of this, as six : $3 - \sqrt{5}$. Therefore the diameter of the sphere is incommensurable to the side of an inscribed dodecahedron, both in itself and in its power.

If the side, or linear edge, of a dodecahedron be s, its surface will be

$$15\,s^2\sqrt{1 + \tfrac{2}{3}\sqrt{5}} = 20.6457788\,s^2\text{: and its solidity}$$

$$\frac{5\,s\sqrt{47 + 21\sqrt{5}}}{40} = 7.66311896\,s^3.$$

If the radius of the sphere that circumscribes a dodecahedron be r, then is

$$\text{its side or linear edge} = \frac{\sqrt{15} - \sqrt{3}}{3}\,r,$$

$$\text{its superficies} = 10\,r^2\sqrt{2 - \tfrac{2}{3}\sqrt{5}}\text{, and}$$

$$\text{its solidity} \quad \frac{20\,r^3}{8} \qquad \frac{\sqrt{u + \sqrt{5}}}{30}$$

The sides of a dodecahedron inscribed in a sphere is equal to the greater part of the side of a cube inscribed in the same sphere, and cut according to extreme and mean proportion. If a line be so cut, and the lesser segment be taken for the side of a dodecahedron, the greater segment will be the side of a cube inscribed in the same sphere. The side of the cube is equal to the right line which subtends the angle of a pentagon, of the dodecahedron inscribed in the same sphere.

DODECASTYLE, an edifice having twelve columns in front.

DOG-LEGGED STAIRS, such as are solid between the upper flights; or those which have no well-hole; and the rail and balusters of both the progressive and retrogressive flight, fall in the same vertical plane. The steps are fixed to strings, newels, and carriages; and the ends of the steps of the inferior kind terminate only on the side of the string, without any housing.

No. 1. The plan.—*a* the seat of the newel; *g* the seat of the upper newel.

The dotted lines represent the faces of the risers, and the continued lines the nosings of the steps.

No. 2. The elevation.—A B the lower newel, the part B C being turned; G H the upper newel; D E, F G, the lower and upper string-boards, framed into the newel; K L a joist framed into the trimmer I; *k l*, *n o*, *q r*, *&c.*, the faces of the risers; *m n*, *p q*, *s t*, the heads, or cover-boards; *m*, *p*, *s*, *&c.*, nosings of the steps; M O, F Q, the upper and lower ramps.

To describe the ramps.—Suppose the upper one to be drawn; produce the horizontal part, H M, of the rail to P: draw M N perpendicular to P H, and produce the straight part, B O, to N: make N O equal to N M: draw O P at right angles to B N: from P, as a centre, describe the arc M O: and describe another concentric circle to meet the under side of the rail, and the sloping part B O; and the ramp will be completed.

R S, the story-rod; this is a necessary article in fixing the steps; for if a common measuring rule be used for this purpose, the workman will be very liable to err either in excess or defect, and thus render the stairs extremely faulty; which cannot be the case if the story-rod be applied to every riser, and if the successive risers be regulated thereby. When steps are put up without the use of the story-rod, the smallest error is liable to multiply.

In the construction of dog-legged staircases, the first thing is to take the dimensions of the stair and the height of the story, and lay down a plan and section upon a floor to the full size, representing all the newels and steps; then the situation of the carriages, pitching-pieces, long bearers, and cross bearers, will be ascertained, as also of the string-boards.

The quantity of room allowed for the stairs, and the situation of the apertures and passages, will determine whether there are to be quarter-paces, half-paces, one-quarter winders, or two-quarter winders. In order to give all the variety possible, we shall suppose the flight to consist of two-quarter winders.

The strings, rails, and newels, being framed together, they must be fixed with temporary supports; the string-board will show the situation of the pitching-pieces, which must be put up next in order, wedging one end firmly into the wall, and fixing the other to the string-board; this being done, pitch up the rough strings, and thus finish the carriage part of the flyers. In dog-legged staircases, the steps and risers are seldom glued up, except in cases of returned nosings; suppose them, therefore, to be of separate pieces; proceed to

put up the steps: place the first riser in its situation, having fitted it down close to the floor; the top being brought to a level at its proper height, and the face in its right position, fix it with flat headed nails, driving them obliquely through the bottom part of the riser into the floor, and then nailing the end to the string-board; proceed then to cover the riser with the first tread, observing to notch out the farther bottom angle opposite the rough strings, so as to make it fit closely down to a level on the top side, while the under side beds firmly upon the rough strings at the back edge, and to the riser towards the front edge: nail down the tread to the rough strings, driving the nails from the seat, or place on which the next riser stands, through that edge of the riser into the rough strings, and then nailing the end to the string-board; begin with the second riser, having brought it to a breadth, and fitted it close to the top of the tread, so that the back edge of the tread below it may entirely lap over the back of the riser, while the front side is in its regular vertical position: nail the head of the riser, from the under side, taking care that the nails do not go through its face, and thereby spoil the beauty of the work.

Proceed in this manner, with tread and riser alternately, until the last parallel riser. The face of this riser must stand the whole projection of the nosing back from the face of the newel. Then fix the top of the first bearer, for the first winding tread, on a level with the top of the last parallel riser, so that the farther edge of this bearer may stand about an inch forward from the back of the next succeeding riser, for the purpose of nailing the treads to the risers upwards, as was done in the treads and risers of the flyers; and having fitted the end of this bearer against the back of the riser, and nailed or screwed them fast together, fix a cross-bearer, by letting it half its thickness into the adjacent sides of the top of the riser, and into the top of the long bearer, so as not to cut through the horizontal breadth of the long bearer, nor through the thickness of the riser, as this would weaken the one, and spoil the look of the other. Then fix the riser to the newel, driving a nail obliquely from the top edge of the former into the latter: then proceed to put down the first winding tread, fitting it close to the newel, in the bird's-mouth form. Proceed in this manner with all the succeeding risers and treads, always fixing in the bearers, previously to laying each successive tread, until the steps round the winding part are entirely completed. Then proceed with the upper retrogressive range of flyers as with those below. Fit the brackets into the backs of the risers and treads, so that their edges may join each other on the sides of the rough strings, to which they are fixed by nails, and thus the work is completed. Some workmen do not mind the close fitting of the riser; but it certainly makes the firmest work.

In the best kind of dog-legged stairs, the nosings are returned; sometimes the risers are mitred to the brackets, and sometimes mitred with quaker-strings: in the latter case, a hollow is mitred round the internal angle of the under side of the tread, and the face of the riser. Sometimes the string is framed into the newel, and notched to receive the ends of the steps; the other end having a corresponding notch-board, and the whole flight is put up like a step-ladder. In order to get the lower part for the turning, set the thickness of the capping on the return string-board, and where that falls on the newel below, is the place of the lower limit for the turning.

To find the section of the cap of the newel for the turner.—Draw a circle to its intended diameter: draw a straight line from the centre to any point without the circumference, and set half the breadth of the rail on each side of that line; through the point draw a line parallel to the middle straight line, and the extreme lines will contain the breadth of the rail: draw any radius of the circle, and set half the breadth of the rail from the centre towards the circumference; through the point where this breadth falls, draw a concentric circle; from the point where this circle cuts the middle line of the rail, draw two lines to the points where the breadth of the rail intersects the outer circle, and these lines will show the mitre. *See* HAND-RAILING and STAIR-CASING.

DOGS, otherwise termed *andirons* or *endirons*, *creepers*, &c. iron standards used in the olden times to support the logs of wood when consumed for fuel. The distinction between the andirons and creepers consists in the former being of a larger size than the latter; the use of the andirons was to support the logs, and of the creepers to keep the brands off the hearth. ENDIRONS.

DOG-TOOTH, an ornament very prevalent in edifices of the Early English style, in which it forms a very marked feature. It consists of a pyramidal flower of four leaves, so disposed as to have the space between the two adjacent leaves in the centre of the sides of the pyramid; a series of such ornaments is very frequently seen inserted in a hollow moulding.

DOME, a term applied to a covering of the whole or part of a building. The Germans call it *Dom*, and the Italians *Duomo*, and apply the word to the principal church of a city, although the building may not have any spherical or polygonal dome. From this and other circumstances we may infer the term to be derived from the Latin *Domus*, house.

A dome is an arched or vaulted roof, springing from a polygonal, circular, or elliptic plan; presenting a convex surface on the outside, or a concavity within, so as that every horizonal section may be of a similar figure, and have a common vertical axis. According to the plan from which they spring, domes are either circular, elliptical, or polygonal; of these, the circular may be spherical spheroidal, ellipsoidal, hyperboloidal, paraboloidal, &c. The word dome is applied to the external part of the spherical or polygonal roof, and cupola to the internal part. Cupola is derived from the Italian *cupo*, deep, whence also our word cup. But cupola and dome are often used synonymously, although perhaps incorrectly. Such as rise higher than the radius of the base, are denominated *surmounted domes;* those that are of a less height than the radius, are called *diminished* or *surbased;* and such as have circular bases, are termed *cupolas*.

The remains of ancient domes are generally spherical in their form, or built of stone or *tufo*. Ruins of numerous ones still exist in the neighbourhood of Rome and Naples. They were frequently used among the Romans, after the accession of Augustus, in whose reign, the use of the arch, and consequently of domes, first became common. The arch, indeed, is of Grecian origin, though in all the ancient edifices of that country, we do not meet with a single instance of a built dome: that which covers the monument of Lysicrates, being only a single stone, can only be looked upon as a lintel: and the invention of this species of vault seems justly attributed to the Romans, or Etrurians.

Of the ruins of domes in and near Rome, the principal are the Pantheon, and the temples of Bacchus, Vesta, Romulus, Hercules, Cybele, Neptune, and Venus, and also some of the chambers of the Thermæ. The most magnificent dome of antiquity is that of the Pantheon, at Rome, built in the reign of Augustus, and supposed to be a chamber of the great baths of Agrippa. It is still entire, and consists of a hemispherical concavity, enriched with coffers, and terminating upwards in an aperture, called *the eye*. The exterior rises from several degrees, in a sloping direction, nearly tangent to the several internal quoins, and presenting to the spectator

the truncated segment of a sphere, considerably less than a hemisphere. The diameter of the dome internally is 142 feet 8½ inches; the circular opening at the top in the centre 28 feet 6 inches in diameter; the height from the top of the attic 70 feet 8 inches. The interior of the dome is ornamented with five rows of square compartments, and as these converge towards the top, each row is considerably larger than that immediately above it. Each of the large squares contains four smaller ones sunk one within the other. It is supposed that these were decorated with plates of silver. The base of the dome externally consists of a large plinth with six smaller plinths or steps above it; and in the curve of the dome a flight of steps is formed which leads to the opening at the top of the dome. From the drawings of Serlio, it appears that similar flights of steps were formed at intervals all round the dome, but these are now covered with lead. The dome is constructed of bricks and rubble. The thickness at the base is about 17 feet; at the top of the highest step, 5 feet 1½ inches; and at the top of the dome, 4 feet 7 inches. The circular wall which supports the dome is 20 feet thick, but is divided by several large openings, and has discharging arches of brick. The dome of the Pantheon is incombustible, and is perhaps the cheapest as well as the most durable and unconsumable roof which could have been erected over so large a building.

The dome of the temple of Bacchus is also internally hemispherical, though without coffers. Externally it is now covered with a common roof, which may have been the original form; such a roof is also to be seen over the dome of the temple of Jupiter, in the palace of Diocletian, at Spalatro.

The dome of one of the chambers of the Thermæ of Catania was 111 feet in diameter. In the Thermæ of Titus there are two domes, each 84 feet in diameter; and in the baths of Constantine there was one of 76 feet. There were three domes in the baths of Diocletian, of which two still remain; one is 73 feet 6 inches in diameter, and the other 62 feet 3 inches. Judging from those that remain, it would seem that in the Thermæ they were lighted from the top, in the same manner as in the dome of the Pantheon. In the neighbourhood of Puzzuoli there is a circular edifice which has a dome built of pumice-stone, and volcanic tufa: its diameter is about 96 feet. The temple of Minerva Medica at Rome, was on the plan, a polygonal dome of ten sides, without any opening at the top. Domes were sometimes constructed on corbels by the ancients. In one of the octagonal rooms of the enclosure round the baths of Caracalla the corbels which supported the dome still remain, and at Catania there is a spherical dome covering a square vestibule.

The dome of Santa Sophia, at Constantinople, built in the reign of Justinian, ranks next to the Pantheon in point of antiquity, and is the most remarkable and the earliest constructed after those of the Romans. Anthemius of Tralles, and Isidorus of Miletus, were the architects. Anthemius had promised to raise a dome over this edifice, of such magnitude as to eclipse the magnificence of the Roman Pantheon. With this view, he erected four pillars at the angles of a square, at about the distance of 115 feet from each other, and nearly of the same altitude. The church was to be of the form of a cross, and vaulted with stone; he therefore threw arches over the pillars, and filled up the angular spaces between the archivaults, till he had gradually shaped them into a complete circle, at the level of the extradoses of the arches. On the ring thus formed, the dome was raised, being the first ever built on pendentives. The pressure of the eastern and western arches was resisted by four walls almost solid, forming transepts, and running longitudinally, two from the north, and two from the south sides of the pillars, to the distance of about 90 feet. The east and west arches were abutted upon by half-domes, resting on cylindrical walls, which, it was supposed, would have been sufficient to resist the pressure of the arches on the north and south; but in this the architect was mistaken; for the superstructure gave way towards the east, and, at the end of a few months, fell, taking with it the half-dome on that side. After the death of Anthemius, the superintendence of the building devolved on Isidorus, who strengthened the eastern pillars, by filling up certain voids left by his predecessor; but when the dome was turned upon them, the east end proved still too weak for the support of so great a load, and again gave way, before the work was completed. In order to counteract this thrust on the east, Isidorus now built strong pillared buttresses against the eastern wall of a square cloister that ran round the building; from which he threw flying buttresses over the void, and then raised the dome a third time, but with very little success; for though every precaution was taken to lessen its weight, by using pumice-stone and other light materials, and by reducing its thickness, the arches were so much fractured, that he was under the necessity of filling up the large arcades on the north and south sides, with arches of less dimensions, in three stories.

We have mentioned these circumstances, to show that the architects of the age to which this building is referred, were not so well acquainted with the principles of dome-vaulting, as those of more modern date: for the latter would probably have hooped or chained such a dome immediately over the arches and pendentives, so as to confine its pressure to a perpendicular thrust, or nearly so. Such was the case, in the far more ponderous dome of St. Peter's, at Rome, erected by Michael Angelo; and such, more recently, was the practice of our countryman, Sir Christopher Wren, in the cupola of St. Paul's, at London. The present dome, however, of Santa Sophia, was reconstructed by the nephew of Isidorus. It rests on the square formed at the intersection of the arms of the Greek cross; the diameter being about 111 feet, and the dome 40 feet high, and is supported by corbellings placed in the angles of the square. These corbels are surmounted by a kind of cornice on which rests a circular gallery. The lower part of the dome has a row of windows adorned with columns on the exterior, and the top is surmounted by a lantern on which is a cross. The dome of Anthemius and Isidorus, was not so high; and was partly destroyed by an earthquake a few years after its construction. In rebuilding it, the nephew of Isidorus used a very light white brick, made at Rhodes, and much lighter than the common brick.

The dome of St. Mark, at Venice, erected about the year 973, and that of the cathedral at Pisa, built early in the eleventh century, are both upon the same plan with the preceding. The church of Saint Mark, built in the tenth century, has five domes; the central dome being much larger than the others. Each dome is enclosed within four pieces of semi-cylindrical vaulting together forming a square; in the angles of this square are four corbels, which gather in the circular base of each dome. In 1523, Sansovinus, the architect, repaired the great dome, and placed a circle of iron round it to prevent its falling. A similar precaution was taken with one of the smaller domes by Andrew Tirali, in 1735, with the same successful result.

The dome of San Vitale at Ravenna, is of very curious construction. The plan of the lower part is that of a regular octagon, supported by eight piers at the angles of the dome. Between these angles are seven tall niches divided into two stories. The lower part of these niches is open, and adorned with columns. The remaining side of the dome is an arch of

the same diameter and elevation as the niches this arch forming an entrance. Above these the wall sustains a hemispherical dome, the plan being a circle within an octagon. Corbels are not employed at Santa Sophia, but the arches support the gathering over, which forms the circular base of the dome. In the base are eight windows, each window being divided in the centre by a column supporting two small arches. The dome itself is built with a double row of pipes, hollow at one end and pointed at the other, so that the point of one is received in the hollow of the preceding one, continuing thus in a spiral line until they finish at the top. Both the exterior and the interior of the dome are covered with mortar.

In 1298, the cathedral of Santa Maria del Fiore, was begun at Pisa, by the celebrated Arnolfo Lusii; but he died two years after, and no architect could be found who would undertake to execute the dome upon the vast plan that its projector had designed: it consequently remained unfinished for one hundred and twenty years; when, in a professional convocation, Philip Brunelleschi was permitted to attempt its completion. (*See* Brunelleschi.) Notwithstanding the opposition he met with, and the vapouring sarcasms with which he was treated by his contemporaries, who held his scheme to be impracticable, he carried on the building, and completed the cupola, in a manner worthy of his great reputation. This dome, which is octangular, and of great elevation, is formed of two vaults, with a vacancy between them; and is supported merely by the springing wall, without the aid of buttresses, though its dimensions exceed those of all the ancient Roman domes, with the sole exception of that of St. Peter's.

The church of St. Peter's, at Rome, is the largest temple ever built: it was begun by Bramante, in 1513, and carried on successively by Raphael, San Gallo, and Michael Angelo, the latter of whom designed the dome as it now appears. The following description, extracted from the "Encylopédie Méthodique," and the "Penny Cyclopædia," will enable the reader to form some idea of this superb work.

"The dome, which is double, is circular on the plan. The internal dome is constructed on double consoles, instead of corbellings. The double consoles are crowned with a small cornice, forming an impost for eight arches, from the upper part of which springs the dome; on the top is a lantern-light, which is not apparent externally. Up to this time domes had been constructed on walls and corbellings, but in St. Peter's at Rome a new plan was adopted. The dome of St. Peter's stands upon four piers, 61 feet 11 inches high, and 30 feet 10 inches thick, measured in a straight line with the arches. From the arches spring the corbellings, which are finished by an entablature. Upon this entablature is a plinth. The plinth is externally an octagon, and internally a circle. The external diameter of the octagon is 192 feet 9 inches, and the internal circle 134 feet 8½ inches; the thinnest part of the wall, between the octagon and the circle, is 29 feet 3 inches. On the plinth is a circular stylobate, 28 feet 6½ inches thick. This thickness is divided into three parts by a circular passage 5 feet 10 inches wide; the two walls on each side of this passage are, respectively, the internal wall 14 feet 7½ inches thick, and the external 8 feet. In the internal wall are other smaller passages, 2 feet 10 inches wide, forming flights of steps communicating with the four spiral staircases formed in the thickness of the wall of the drum of the dome. Above the circular stylobate, which is 12 feet 4½ inches high, is placed the drum of the dome, which is 10 feet 1½ inch thick, measured to the inside line of the pilasters, which decorate the interior of the dome. The pilasters themselves are 1.78 feet thick in addition. The construction is formed of rubble and fragments of brick. The interior is formed with bricks stuccoed. Externally the work is faced with thin slabs of travertine stone. The drum is pierced with 16 windows, 9 feet 3¾ inches wide, and 17 feet high. The walls are strengthened on the outside, between the windows, with 16 buttresses, constructed with solid masonry. These buttresses are 13 feet 3 inches wide, and 51 feet 6 inches in height from the base to the top of the entablature. Each buttress is decorated and strengthened with half-pilasters, and terminates with two coupled columns engaged, the diameter of which is 4 feet; the order is Corinthian. When the base of the dome had been built to the height of the entablature of the drum, Michael Angelo died; but some time before his death he had caused a model to be made, with ample details, to which he added drawings and instructions. After his death Pirro Ligorio and Vignola were appointed the architects. Giacomo della Porta, the pupil of Vignola, followed his master as architect to the cathedral; but although the designs of Michael Angelo were strictly followed, the dome itself was constructed under the pontificate of Sixtus V. Sixtus gave Giacomo della Porta as a colleague, Domenico Fontana, by whom the dome was constructed.

"On the constructions of Michael Angelo a circular attic was first formed, 19 feet 2¼ inches high, and 9 feet 7 inches thick. This attic is strengthened externally by 16 projections, 2 feet 11 inches deep, and 6 feet 4½ inches wide, placed over the buttresses of the dome; on the attic rises the double dome, the internal diameter of which at the base, is 138 feet 5 inches. The curve externally is an arc of a circle whose radius is 84 feet 1.62 inches. To the height of 27 feet 8 inches from the attic the dome is solid. At the base the thickness is 9 feet 7 inches; and as the external dome is raised higher than the internal dome, the thickness is increased as the curve ascends, so that where the dome is divided the thickness is 11 feet 4 inches. The circular space which divides the two domes is 3 feet 2¼ inches wide; the internal dome is 6 feet 4 inches thick; and the height from the attic to the opening of the lantern is 83 feet 10 inches. The diameter of the lantern is 24 feet 10 inches. The external dome is 2 feet 10½ inches thick, where it separates itself from the internal dome; and it is strengthened externally by 16 projecting bands of the same thickness. The dome is pierced with three rows of small windows, as the curves of the dome are not concentric, the space between them becomes wider as it rises; so that at the opening of the lantern the space is 10 feet wide. These domes are joined together by 16 walls or spurs, diminishing in thickness as they ascend to the lantern; at the base they are 8 feet thick, and at the summit 3 feet. The base of the lantern is arched, and pierced with small windows. Above the two domes is a circular platform, surrounded with an iron gallery. In the centre rises the lantern on a stylobate broken into 16 parts, forming projecting pedestals, above which are buttresses similar to the buttresses of the drum, decorated externally with coupled Ionic columns, 17½ inches in diameter. The space between the buttresses is filled with arched openings, which give light to the lantern. The external diameter of the lantern is 39 feet; the internal diameter 25 feet 6¾ inches; and the height from the platform to the top of the cross is 89 feet 7½ inches. The whole height, from the external plinth of the dome to the cross, is 263 feet. The total height internally, to the top of the dome of the lantern, is 387 feet.

"Sixtus V. covered the external dome with lead, and the bands with bronze gilt. During the construction of the dome it is believed that only two circles of iron were placed round the masonry, one of which was placed on the outside of the internal dome, at about 36 feet from its springing, and one foot above the division of the domes. The bands of iron of

which this circle is composed are 3 inches wide by $1\frac{3}{4}$ inches thick. A similar circle is placed about the middle of the solid part of the dome at about 17 feet 6 inches above the springing of the internal dome. Near the top of the internal dome there are several holes, at the bottom of which upright iron bars appear. These bars are said to be the connecting rods which keep together other circles of iron placed at different heights within the masonry, which are finally terminated by a circle round the eye of the dome.

"The domes were constructed with such haste, that sufficient time was not allowed to the work to form solid beds as it was carried up, in consequence of which a great number of vertical settlements took place, and the circle of iron round the internal dome was fractured. To obviate the danger arising from these settlements, six circles of iron were placed round the external dome at different heights, and the broken circle of the internal dome was repaired. The first circle was placed above the cornice of the external stylobate, or continuous plinth, on which the buttresses stand; the second circle was placed above the cornice of the buttresses; the third, above the attic, at the springing of the external dome; the fourth, half way up the external dome; and the fifth under the base of the lantern. A sixth was shortly after placed at one foot below where the dome divides itself. The iron bands are flat, from 16 to 17 feet long, $3\frac{1}{2}$ inches wide, and $2\frac{2}{12}$ inches thick. At one end of the pieces of iron a hole is made; the other end is turned up, and passed through the eye of the next band. The whole of these bands are fixed with iron wedges, driven into the rubble with mallets. Sheets of lead are placed under the iron circles." (*Coupole, Encyclopédie Méthodique; 'Architecture.'*)

St. Paul's cathedral, London, the workmanship of the great Sir Christopher Wren, was begun in 1685, and finished in 1710. "The dome is placed over the intersection of the four naves. The ground plan is a regular octagon, each face of which is 44 feet $8\frac{3}{4}$ inches wide: four of these sides are formed by the four great arches of the naves; the other four sides are formed by false arches of the same size; in each of these arches there is a great niche, the base of which is pierced with two arches. By this means eight supports are obtained instead of four, and the corbellings do not project too much, as in other similar constructions. The corbellings gather in a circle, the diameter of which is 104 feet 4 inches, the octagon base being 107 feet. The corbellings are surmounted by a complete entablature, 8 feet three inches high, decorated with consoles. The drum is set back 3 feet $2\frac{1}{4}$ inches from the face of the frieze, and this intermediate space is occupied by two steps and a seat. The cornice is 98 feet $9\frac{3}{4}$ inches from the pavement. The height of the drum from the top of the seat is 62 feet $6\frac{1}{2}$ inches to the springing of the internal dome. The wall forming the drum is inclined internally 4 feet $11\frac{1}{2}$ inches, or about the 12th part of its height. This was designed by the architect to increase the resistance of the walls to the united pressure of the large internal vault, and the conical dome which carries the lantern.

"The interior of the drum is decorated with a continuous stylobate, on which is an order of Corinthian pilasters. The 32 spaces between the pilasters are filled with 24 windows and eight large niches. Externally the drum is decorated with an order of 32 Corinthian columns engaged, which are united to the wall of the drum by eight solid constructions in masonry. In each space between the constructions there are three intercolumniations, the columns being joined at their bases by wall pierced with arches. The external colonnade is surmounted by an entablature; behind this is a terrace, formed by the recessing back. The attic is 22 feet $4\frac{1}{4}$ inches high from the top of the balustrade to the under side of the cornice of the attic. Above the internal order of the drum rises the interior dome, the diameter of which at the springing is 102 feet $2\frac{3}{4}$ inches by 51 feet in height. The top of the dome has a circular opening 14 feet $10\frac{3}{4}$ inches in diameter.

"Above the attic are two steps, from which the external dome springs. The external dome is constructed of wood, covered with lead, and decorated with projecting ribs forming panels, curved at the ends. This dome terminates with a finishing which joins the base of the lantern: the circular gallery formed on the finishing is 274 feet 9 inches above the pavement of the nave. The lantern is supported on a conical tower, terminated by a spherical dome. This tower, which is joined to the internal dome at its base, disengages itself from it at the height of 8 feet 6 inches above the springing of the same. The perpendicular height of this tower is 86 feet 9 inches, and the walls are inclined 24 degrees from the perpendicular, the diameter of the base is 100 feet 1 inch measured externally, and 34 feet 1 inch at the springing of the spherical dome which finishes it. The wall of this tower is built of brick, and is 1 foot 7 inches thick, with circular rings of masonry, fastened with iron bands. The spherical dome at the top of the tower has an opening 8 feet in diameter at the summit. Between the attic and the wall of the tower are 32 walls or buttresses, which also serve to bear the ribs of the wooden external dome."—*Penny Cyclopædia.*

About the same time that Wren built the dome of St. Paul's, Hardouin Mansard, a French architect, constructed the dome of the Invalides at Paris. The plan of this dome is a square, in which is inscribed a Greek cross; in the angles of the square there are four chapels. The dome is raised in the centre of the Greek cross; the base supporting it is an octagonal figure, with four large and four small sides. The dome, which is double, rises from a springing which is common to both. The lower or internal dome constructed with masonry is spherical. The outer dome is of a spheroidal form, constructed of stone at the base, and of brick above. It is framed of wood and covered with lead, like St. Paul's, London, but the construction is much heavier. The total height to the top of the cross which surmounts the lantern is 330 feet.

The modern Pantheon at Paris, formerly the church of St. Geneviève, was built by J. G. Soufflot, who distinguished himself by his architectural works, in the reign of Louis XV. The dome, which is lofty, is sustained by four pillars, arched over the cross parts. The angular spaces are filled up with pendentives, terminating in a circular ring, on which a cylindrical wall is built, supporting the cupola. In the latter particular it is similar to St. Paul's.

Of wooden domes, that of the Halle du Blé, at Paris, is an excellent example; it being more than 200 feet in diameter, and only a foot in thickness.

A new material has been lately employed in the construction of the dome of the church of St. Isaac, at St. Petersburg, erected under the direction of the Chevalier de Montferrand. An account of the construction is given by Mr. Godwin as follows:—"The walls of the dome are carried up in solid construction of brick, with tiers of stone-bond, and are above 8 feet thick. On the level of the top of the cornice of the circular colonnade which girds the drum, there is a series of twenty-four cast-iron ribs, the feet of which rest on a cast-iron plate 7 feet wide, which runs quite round the circumference. At their head all the ribs are attached to a horizontal plate or curb, 6 feet 3 inches wide, which follows the periphery of the dome. At this height the rib is divided into 2, the one part about 12 feet 6 inches deep, following

the sweep of the inner dome for a height of 20 feet, is at its summit bolted to a cast-iron perforated cylinder, 21 feet in diameter, and 7 feet high; this forms the centre aperture at the summit of the inner dome. The other part follows the line of an intermediate cone, with a catenary outline, and similar to the one in St. Paul's; it is also 21 feet long, and 2 feet 6 inches deep, and perforated to render it lighter. At this height the heads of the ribs are again secured to another horizontal plate or curb, which forms a complete circle, and is 3 feet wide; and this curb and the ribs are tied to the cylindrical opening of the inner dome, already mentioned, by radiating beams 2 feet 3 inches deep. The conical ribs have then another length of 21 feet, and their heads are again connected by another horizontal plate, from which spring the circular ribs, about 16 feet long, forming a dome to the intermediate cone, and their heads are also bolted to a cylinder, 8 feet 6 inches in diameter, and 18 inches high. But the upper portions of the ribs diverge at top, so as to form a base for the octagonal cupolino, which consists of a series of cast-iron story-posts, ribs, and bracketings, inclusive of the dome of the cupolino, with its ball and cross at the apex, which last are of brass-gilt. The filling in between the ribs consists of pots, the surfaces of which are subsequently rendered with plaster, and painted with sacred subjects. The external face of this outer dome is covered with bronze gilt in three thicknesses of leaves of ducat gold. The whole entablature and flat, and the balustrade over the peristyle of the drum of the cupola, likewise consist of cast and wrought iron framing, faced with plates of copper, to form the profiles and mouldings. The 24 pedestals of this balustrade carry winged angels of bronze, above 9 feet high, each of a single casting.

"The quantity of metal employed in the work is as follows:—

Ducat gold	247 lbs.
Copper	$52\frac{1}{2}$ tons
Brass	$321\frac{1}{2}$ "
Wrought-iron	$524\frac{1}{2}$ "
Cast-iron	1068 "
	$1966\frac{1}{2}$ tons 247 lbs.

"The roofing is wholly of iron, covered with copper. The raising of the monolithic shafts of the 24 columns of the exterior peristyle of the dome—each of which weighed nearly 66 tons—to the height of 150 feet, was an operation requiring considerable skill. The first column was raised on the 17th November, 1837, and in two months the 24 columns were completely fixed.

"The skeleton of the entablature of the peristyle of the dome is of cast and wrought iron, resting on the columns, and affixed to them by wrought-iron pins, which are let a considerable depth into the shafts, and the frame-work is also let into the cylindrical wall of the dome, securely affixed to three templates. The cornice, with its modillions and mouldings, rests on cast-iron corbels; the caissons and rosettes of the inner soffit also rest on cast-iron girders.

"The careful skill with which the architect has fulfilled his part, and the feeling for decorative art with which he has embellished the church of St. Isaac, render it one of the most striking edifices of the nineteenth century."

All the ancient Roman domes are on the convex side a much less portion of a sphere than a hemisphere; but those, from the completion of the church of Santa Sophia, to the finishing of St. Paul's cupola, are of the surmounted kind, approaching in a greater or less degree to the proportion of towers, or spires, which were so much admired and adopted in the middle ages. The sides of the section of St. Paul's dome are struck with centres in the base line, which, if continued, would meet in an angle in the axis of the dome. Since the revival of Grecian architecture, the contour of the old Roman dome has also been revived, especially in cases where other parts of the building are decorated with any of the orders. Exterior domes can never be correctly applied to buildings in the pointed style of architecture.

The following are the admeasurements of some of the principal domes in Europe, taken from Mr. Ware's "Tracts on Vaults and Bridges:"—

Domes of Antiquity.

	Feet in diameter taken externally.	Height from the ground line.
Dome of the Pantheon	142	143
" Minerva Medica, at Rome	78	97
" Baths at Caracalla	112	116
" Baths at Diocletian	74	83
Temple of Mercury	68	
" Diana	98	78
" Apollo	120	
" Proserpine and Venus	87	77

Domes of comparatively Modern Times.

Santa Sophia, at Constantinople	115	201
Mosque of Achmet, "	92	120
San. Vitate, at Ravenna	55	91
San. Marco, at Venice	44	

From the time of Brunelleschi to the present period.

Santa Maria del Fiore, at Florence	139	310
The Chapel of the Medici	91	199
Baptistry, at Florence	86	110
Cathedral of St. Peter, at Rome	139	330
Chapel of the Madonna della Salute, at Venice	70	133
Chapel of the Superga, at Turin	64	128
" Invalides, at Paris	80	173
" Val de Grace, Paris	55	133
" Sorbonne, Paris	40	110
Pantheon, or St. Geneviève, Paris	67	190
Cathedral of St. Paul's, London	112	215

In the reigns of queen Elizabeth, and her successor king James I., square turrets, surmounted with domes resembling a bell in their outline, were much used.

Domes are sometimes made convex below, and concave above; the former being a much greater portion of the side than the latter: these may be denominated Moresque, Turkish, or Hindoo.

Mr. Bunce invented a dome that requires no centering; in this construction, all the abutting joints are continued in uninterrupted vertical planes; but the horizontal joints of every two stones break on the middle of the stones on either side; so that every alternate stone of a course projects upwards, and leaves a recess for the insertion of the stones of the next course. Upon this principle, the intervals, as the building approaches nearer the top, becomes more wedge-formed, and, the interior circumference being less than the exterior, the stones can be inserted only on the outside: consequently, if made so exact as just to fit into their places, they cannot fall inwardly. This mode of joining stones may be convenient, as requiring no centering; but unless the courses be nicely equilibrated, it is more liable to burst, than when a dome is constructed in the ordinary manner, since every row of stones, from the base to the top, forms an arch independent of the rest.

The equilibrium and pressure of domes is very different from that of common arching, though there are some properties common to both. Thus, in cylindrical and cylindroidal vaulting, of uniform thickness, if the tangent to the arch at the bottom be perpendicular to the horizon, the vault cannot stand; neither can it be built with a concave contour in whole, or in part; and to bring an arch to an equilibrium, whether its section be circular or elliptical, the intrados being given, both extremities of the arch must be loaded, *ad infinitum*, between the extrados of the curve which runs upwards, and the vertical assymptote rising from each foot. So, in thin domes, of equal thickness, if the curved surface rise perpendicularly from the base, it will burst at the bottom, whatever be the contour.

Yet, though dome-vaulting, in this particular, agrees with common arching, they differ materially in several other points. For, in order to equilibrate the figure of the former, after the convexity has been carried to its full extent of equilibrium around, and equidistant from the summit on the exterior side, the curvature may be changed into a concavity: here the interior circumference of the courses is less than the exterior, and therefore, whatever the pressure towards the axis, the course cannot fall inwardly, without squeezing the stones into a less compass. Hence a vault may be executed with a convex surface inwardly, and a concave surface outwardly, and be sufficiently firm.

The strongest form of a circular vault, required to bear a weight on its top, is that of a truncated cone, similar to the exterior dome of St. Paul's, London, of which it is impossible to conceive any force acting on the summit, that would be capable of disturbing its equilibrium: for the pressure being communicated in the sloping right line of the sides of the cone, perpendicular to the joints, the conic sides have no tendency to bend to one side more than to another; the gravity of the materials towards the axis, being counteracted by the abutting vertical joints.

In dome-vaulting, the case is very different: for here the contour being convex, there is a certain load, which, if laid on the top, must burst it outwardly, which weight becomes greater in proportion as the contour approximates towards the chords of the arches of the two sides, or to a conic vaulting on the same base, carried up to the same altitude, and ending in the same circular course. For example, suppose a horizontal line, tangent at the vertex, proceed from the key-stone downwards, course by course; it will be evident, that every successive coursing-joint may be made to slant as much, and consequently, that the pressure of the arch-stones of any course towards the axis will be so great, as to be more than adequate to the resistance of the weight of all the superincumbent parts. Hence it may be clearly deduced, that there is a certain degree of curvature to be given to the contour, which will just prevent the stones in any succeeding course from being forced outwardly.

The circular vault, thus balanced, is indeed an equilibrated dome; but, instead of the strongest, it is the weakest of all between its own contour and that of a cone upon the same base, rising to the same height, in a key-stone, or in an equal circular course. The equilibrated dome has therefore the boldest contour; but is the limit of an infinitude of inscribed circular vaults, all of them stronger than itself.

In other respects, circular vaulting differs from straight vaulting in being built with courses in circular rings; and in having the stones in each course of equal length, which pressing equally towards the axis, cannot slide inwardly. Circular vaults may therefore be open at the top; and the equilibrated dome, which, as we have just observed, is the weakest of all, may be made to bear a lantern of equal weight with the part that would otherwise have completed the whole. Domes of flatter contours will bear more, in proportion as they approach nearer to that of a cone: and circular vaults, that are either straight or concave on the sides, if chained at the bottom, may be loaded to any degree, without giving way, until the materials of which they are built be crushed to powder.

The foregoing description of the equilibrium and pressure of domes may be comprehended without any acquaintance with either algebra or fluxions, and will be of use to the ordinary workmen; for the satisfaction of more scientific readers, we subjoin Dr. Robison's theory.

Problem.—To determine the thickness of dome-vaulting when the curve is given, or the curve when the thickness is given.

Plate 1. *Figure* 1.—"Let B b A be the curve which produces the dome by revolving round the vertical axis A D. We shall here suppose the curve to be drawn through the middle of the arch-stones, and that the coursing or horizontal joints are everywhere perpendicular to the curve. We shall suppose (as is always the case) that the thickness K L, H I, &c. of the arch-stones is very small in comparison to the dimensions of the arch. If we consider any portion H A h of the dome, it is plain that it presses on the curve of which H L is an arch-stone, in a direction b C, perpendicular to the joint H I, or in the direction of the next superior element β b of the curve. As we proceed downwards, course after course, we see plainly that this direction must change, because the weight of each course is superadded to that of the portion above it to complete the pressure of the course below. Through B draw the vertical line B C G meeting β b, produced in C. We may take b c to express the pressure of all that is above it, propagated in this direction to the joint K L. We may also suppose the weight of the course H L united in b, and acting on the vertical. Let it be represented by b F. If we form the parallelogram b F G C, the diagonal b G will represent the direction and intensity of the whole pressure on the joint K L.

"We have seen, that if b G, the thrust compounded of the thrust b C exerted by all the courses above H I L K, and if the force b F, or the weight of that course be everywhere coincident with b B, the element of the curve, we shall have an equilibrated dome; if it fall within it, we have a dome which will bear a greater load, and if it fall without it, the dome will break at the joint. We must endeavour to get analytical expressions of these conditions. Therefore draw the ordinates $b\ \delta\ b''$, B D B$''$, C d C$''$. Let the tangents at b and b'' meet the axis in M, and make M O, M P, each equal to b C, and complete the parallelogram M O N P, and draw O Q perpendicular to the axis, and produce b F, cutting the ordinates in E and e. It is plain that M N is to M O as the weight of the arch H A h to the thrust b C, which it exerts on the joint K L (this thrust being propagated through the course of H I L K,) and that M Q, or its equal b e, or δ d, may represent the weight of the half A H. "Let A D be called x, and D B be called y. Then $b\ e = \dot{x}$, and e C $= \dot{y}$ (because b C is in the direction of the element β b). It is plain if we make $\bar{y}$ constant, B C is the second fluxion of x, or B C $= \dot{x}$, and b e and b E may be considered as equal, and taken indiscriminately for $\dot{x}$. We have also b C $= \sqrt{x_2 + y_2}$; let d be the depth or thickness of H I of the arch-stones. Then $d\sqrt{\dot{x}_2 = \dot{y}_2}$; will represent the trapezium H L; and since the circumference of every course increases in the proportion of the radius y, $d\ y\sqrt{\dot{x} + \dot{y}}$ will represent the whole course. If s be taken to represent the sum or aggregate of the quantities annexed to it, the formula will be analogous to the fl..ent of a fluxicn and $s\ d\ y\sqrt{\dot{x}^2 + \dot{y}^2}$ will

represent the whole mass, and also the weight of the vaulting down to the joint H I. Therefore we have this proportion: $s\,d\,y \sqrt{\dot{x}^2 + \dot{y}^2} : d\,y \sqrt{\dot{x}^2 + \dot{y}^2} = b\,e : b\,\text{F} = b\,e : \text{C G} = \delta\,d : \text{C G} = x : \text{C G}$. Therefore $\text{C G} = \dfrac{d\,y\,x \sqrt{\dot{x}^2 + \dot{y}^2}}{s\,d\,y \sqrt{\dot{x}^2 + \dot{y}^2}}$

"If the curvature of the dome be precisely such as puts it in equilibrium, but without any mutual pressure in the vertical joints, this value of C G must be equal to C B, or to $\ddot{x}$, the point G coinciding with B. This condition will be expressed by the equation $\dfrac{d\,y\,\dot{x} \sqrt{\dot{x}^2 + \dot{y}^2}}{s\,d\,y \sqrt{\dot{x}^2 + \dot{y}^2}} = \ddot{x}$ or more conveniently by $\dfrac{d\,y \sqrt{\dot{x}^2 + \dot{y}^2}}{s\,d\,y \sqrt{\dot{x}^2 + \dot{y}^2}} = \dfrac{\ddot{x}}{\dot{x}}$. But this form gives only a tottering equilibrium, independent of the friction of the joints and cohesion of the cement. An equilibrium, accompanied by some firm stability produced by the mutual pressure of the vertical joints, may be expressed by the **formula.** $\dfrac{d\,y \sqrt{\dot{x}^2 + \dot{y}^2}}{s\,d\,y \sqrt{\dot{x}^2 + \dot{y}^2}} > \dfrac{\ddot{x}}{\dot{x}}$, or by $\dfrac{d\,y \sqrt{\dot{x}^2 + \dot{y}^2}}{s\,d\,y \sqrt{\dot{x}^2 + \dot{y}^2}} = \dfrac{\ddot{x}}{\dot{x}} + \dfrac{\dot{t}}{t}$, where t is some variable positive quantity which increases when x increases. This last equation will also express the equilibrated dome, if t be a constant quantity, because in this case: $\dfrac{\dot{t}}{t}$ is $= 0$

"Since a firm stability requires that $\dfrac{d\,y\,\dot{x} \sqrt{\dot{x}^2 + \dot{y}^2}}{s\,d\,y \sqrt{\dot{x}^2 + \dot{y}^2}}$ shall be greater than $\ddot{x}$, and C G must be greater than C B. Hence we learn that figures of too great curvatures, whose sides descend too rapidly, are improper. Also since stability requires that we have $\dfrac{d\,y\,\dot{x} \sqrt{\dot{x}^2 + \dot{y}^2}}{\ddot{x}}$ greater than $s\,d\,y \sqrt{\dot{x}^2 + \dot{y}^2}$, we learn that the upper part of the dome must not be made very heavy. This, by diminishing the proportion of b F to b C, diminishes the angle C b G, and may set the point G above B, which will infallibly spring the dome in that place. We see here also, that the algebraic analysis expresses that peculiarity of dome-vaulting, that the weight of the upper part may even be suppressed.

"The fluent of the equation $\dfrac{d\,y \sqrt{\dot{x}^2 + \dot{y}^2}}{s\,d\,y \sqrt{\dot{x}^2 + \dot{y}^2}} = \dfrac{\ddot{x}}{\dot{x}} + \dfrac{\dot{t}}{t}$ is most easily found. It is $\text{L}\,s\,d\,y \sqrt{\dot{x}^2 + \dot{y}^2} = \text{L}\,\dot{x} + t$, where L is the hyperbolic logarithm of the quantity annexed to it. If we consider $\dot{y}$ as constant and correct the fluent, so as to make it nothing at the vertex, it may be expressed thus:

$\text{L}\,s\,d\,y \sqrt{\dot{x}^2 + \dot{y}^2} - \text{L}\,a = \text{L}\,\dot{x} - \text{L}\,\dot{y} + \text{L}\,t$. This gives us $\text{L}\dfrac{s\,d\,y \sqrt{\dot{x}^2 + \dot{y}^2}}{a} = \text{L}\,\dfrac{\dot{x}}{\dot{y}}t$, and therefore $\dfrac{s\,d\,y \sqrt{\dot{x}^2 + \dot{y}^2}}{a} = t\,\dfrac{\dot{x}}{\dot{y}}$

This last equation will easily give us the depth of the vaulting, or thickness, d, of the arch, when the curve is given. For its fluxion is $\dfrac{d\,y \sqrt{\dot{x}^2 + \dot{y}^2}}{a} = \dfrac{t'\,\dot{x} + t\,\ddot{x}}{\dot{y}}$ and $d = \dfrac{a\,t'\,\dot{x} + a\,t'\,\ddot{x}}{u\,\dot{y} \sqrt{\dot{x}^2 + y^2}}$, which is all expressed in known quantities: for we may put in place of t any power or function of x or of y, and thus convert the expression into another, which will still be applicable to all sorts of curves.

"Instead of the second member $\dfrac{\ddot{x}}{x} + \dfrac{t'}{t}$ we might employ $\dfrac{p\,\ddot{x}}{\dot{x}}$, where p is some number greater than unity. This will evidently give a dome having stability; because the original formula $\dfrac{d\,y\,\dot{x} \sqrt{\dot{x}^2 + \dot{y}^2}}{s\,d\,y \sqrt{\dot{x}^2 + \dot{y}^2}}$ will be greater than $\dot{x}$. This will give $d = \dfrac{p\,a\,\dot{x}^{p-1}\,\ddot{x}}{y\,\dot{y}^p \sqrt{\dot{x}^2 + \dot{y}^2}}$. Each of these forms has its advantages, when applied to particular cases. Each of them also gives $d = \dfrac{a\,\ddot{x}}{y\,\dot{y} \sqrt{\dot{x}^2 + \dot{y}^2}}$ when the curvature is such as in precise equilibrium: and lastly, if d be constant, that is, if the vaulting be of uniform thickness, we obtain the form of the curve, because then the relation of x to x and to y is given.

"The chief use of this analysis is to discover what curves are improper for domes, or what portions of given curves may be employed with safety.

"The chief difficulty in the case of this analysis arises from the necessity of expressing the weight of the incumbent part, or $s\,d\,y \sqrt{\dot{x}^2 + \dot{y}^2}$. This requires the measurement of the conoidal surface, which in most cases can be had only by approximation, by means of infinite series. We cannot expect that the generality of practical builders are familiar with this branch of mathematics, and therefore will not engage in it here; but content ourselves with giving such instances as can be understood by such as have that moderate mathematical knowledge, which every man should possess, who takes the name of engineer.

"The surface of any circular portion of a sphere is very easily had, being equal to the circle inscribed with a radius equal to the arch. This radius is evidently equal to $\sqrt{\dot{x}^2 + \dot{y}^2}$.

"In order to discover what portion of a hemisphere may be employed (for it is evident we cannot employ the whole) when the thickness of the vaulting is uniform, we may recur to the equation or formula $\dfrac{d\,y\,\dot{x} \sqrt{\dot{x}^2 + \dot{y}^2}}{\ddot{x}} = s\,d\,y \sqrt{\dot{x}^2 + \dot{y}^2}$. Let a be the radius of the hemisphere. We have $\dot{x} = \dfrac{a\,y\,\dot{y}}{\sqrt{a^2 - y^2}}$ and $\ddot{x} = \dfrac{a\,\dot{y}^2}{a^2 - y^2|^{\frac{3}{2}}}$. Substituting these values in the formula, we obtain the equation $y^2 \sqrt{a^2 - y^2} = s\dfrac{a^2\,y\,\dot{y}}{\sqrt{a^2 - y^2}}$. We easily obtain the fluent of the second member $= a^3 - a^2 \sqrt{a^2 - y^2}$, and $y = a \sqrt{-\frac{1}{2} + \sqrt{\frac{5}{4}}}$. Therefore, if the radius of the hemisphere be one-half, the breadth of the dome must not exceed $\sqrt{-\frac{1}{2} + \sqrt{\frac{5}{4}}}$, or 0.786, and the height will be 618. The arch from the vertex is about 51° 49′, much more of the hemisphere cannot stand even, though aided by the cement, and by the friction of the coursing joints. This last circumstance, by giving connection to the upper parts, causes the whole to press more vertically on the course below, and this diminishes the outward thrust; but at the same time diminishes the mutual abutment of the vertical joints, which is a great cause of firmness in the vaulting. A Gothic dome, of which the upper part is a portion of a sphere not exceeding 45° from the vertex, and

the lower part is concave outwards, will be very strong, and not ungraceful.

"Persuaded that what has been said on this subject convinces the reader that a vaulting, perfectly equilibrated throughout is by no means the best form, provided that the base is secure from separating, we think it unnecessary to give the investigation of that form, which has considerable intricacy, and shall merely give its dimensions. The thickness is supposed uniform. The numbers in the first column of the table express the portion of the axis counted from the vertex, and those of the second are the length of the ordinates.

A D	D B	A D	D B	A D	D B
0.4	100	610.4	1080	2990	1560
3.4	200	744	1140	3442	1600
11.4	300	904	1200	3972	1640
26.6	400	1100	1260	4432	1670
52.4	500	1336	1320	4952	1700
91.4	600	1522	1360	5336	1720
146.8	700	1738	1400	5756	1740
223.4	800	1984	1440	6214	1760
326.6	900	2270	1480	6714	1780
465.4	1000	2602	1520	7260	1800

"The curve formed according to these dimensions will not appear very graceful, because there is an abrupt change in its curvature at a small distance from the vertex. If, however, the middle be occupied by a lantern of equal, or of smaller weight than the part whose place it supplies, the whole will be elegant and free from defect.

Figure 3 represents four different contours of domes, upon a square plan, No. 5; No. 1, shows a semicircle contour; No. 2, a pointed contour; No. 3, a Turkish, or Mahometan contour; No. 4, a bell-formed contour, as used in the reigns of Elizabeth and James I.

Figure 4 represents five different contours, upon an octagonal plan, No. 6; No. 1, the contour of a dome, the vertical section of which being a semi-ellipsis, with the lesser axis placed horizontal; No. 2, the contour of a semicircular section; No. 3, the contour of a dome, the vertical section of which is a semi-ellipsis, placed upon the greater axis; No. 4, the contour of a dome, the vertical section parallel to either side being the segment of a circle: No. 5, a pointed contour, formed similar to the dome of the cathedral church of S[ta.] Maria del Fiore, at Florence, which was both octangular upon the plan, and pointed in its vertical section.

Figure 5 represents five contours upon a circular plan, No. 6; No. 1, is formed by having its vertical section the segment of a circle, which was the general practice of the Romans, in the exterior form of their domes, as in the Pantheon at Rome; No. 2, a dome with a semicircular axal section, a form very frequently used in modern times; No. 3, an ellipsoidal dome, whose axis is the greater semi-axis of the ellipsis; No. 4, represents a dome with a parabolical contour, the vertical section being that of a curve, and the axis of the parabolical section being the same as that of the dome. This contour is more pointed than any part of an ellipsis; No. 5, represents a dome with an hyperbolical contour, the vertical section being an hyperbola; this is still more pointed than the parabolical dome.

Figure 6 shows four variations of contours: No. 1, pointed like the dome of St Paul's cathedral church, London, which is composed of two arcs of a circle; No. 2, a dome with a small concavity upwards, springing perpendicularly from its base; No. 3, another contour of a dome, with a small concavity at the top, but spreading outwards as it rises from the bottom, with a convexity in its vertical section; No. 4, a dome of the same nature as the last, but dissimilar in its form, the convex part being much quicker. Such forms as the last three may be denominated Moresque, Turkish, or Hindoo, as they are practised by the Moors, Turks, and Hindoos. This form was introduced into England in the reign of Henry VII., and in constant use in the time of Henry VIII. Its use was in the crowning of turrets, as in the octagonal buttresses of Henry the Seventh's chapel, and the towers of King's College chapel, Cambridge: the turrets at the entrance of Christ's College, Oxford, executed by Sir Christopher Wren, are surmounted with domes of this form. The bell-formed dome, *Figure* 3, No. 4, succeeded *Figure* 6, No. 2; examples of it may be seen at Audley-End, in Essex, built in the reign of James I., and in the Tower of London.

It is a property of all domes to have their horizontal sections similar to each other, and to the base of the dome.

What may be properly denominated a Roman dome, is one whose axal section is a semicircle, or the segment of a circle less than a semicircle. Among the ancients, domes were only used in covering whole buildings of a circular plan; but among moderns they are used in covering any apartment, or distinct portion of a building, which too frequently has a very insignificant appearance, and, for want of magnitude, destroys the general contour of the whole, producing a kind of mixed outline at the finish of the edifice; where in most points of view it is completely lost.

In modern architecture, the dome, when used, is generally raised upon a tower, or turret, and by this means the figure is shown more completely than if it were immediately raised from the walls; but care should be taken, that if the place over which it is to be erected be too small, it should not be adopted; and if admitted in an edifice, it should bear a good proportion to the whole mass: when a dome is properly managed, nothing adds more grace or dignity to the termination of an edifice than the domic contour.

Plate III. *Figure* 1.—*Given the plan of a square dome, and one of the axal ribs, at right angles to one of the sides; to find the curve of the angle rib, and the covering.*

The axis of a square dome is the vertical line in which the diagonal planes would intersect each other.

Let A B C D be a plan of the dome; A C and B D the intersections of the diagonal planes; E F the base of the rib; E K the height of the given rib; and the curve line K I H G F, the section of the upper surface, which comes in contact with the boarding. Produce E F to k; divide the curve line K F into any number of equal parts, the more the truer will be the operation; let the parts be F G, G H, H I, I K, which extend upon the straight line F k; the first from F to g, the second from g to h, the third from h to i, and the fourth from i to k; from the points G, H, I, in the curve of the given rib, draw G G′ N, H H′ O, I I′ P, parallel to A D, cutting the base of the rib E F at the points G′, H′, I′, and the half diagonal D E at the points N, O, P; also, through the points g, h, i, draw $n\,g\,n$, $o\,h\,o$, $p\,i\,p$, parallel to A D. Take the intercepted parts G N, H O, I P, between E F and E D, apply them successively to the lines parallel to A D, on each side of F k, from g to n, and from g to n, from h to o, and from h to o, from i to p, and from i to p, and through the points A, n, o, p, k, on each side of F k, draw a curve; then the space, A k D, comprehended between the two curve lines and the side A D of the plan, is the form of the whole covering for each side of the dome.

To find the hip-line of the angle rib whose base is E D.

From the points, N, O, P, E, draw N Q, O R, P S, and E T, perpendicular to E D: make N Q, O R, P S, E T, successively equal to G′ G, H′ H, I′ I, E K: and through the points D, Q, R, S, T, draw a curve, which will be the hip-line.

Figure 2.—A dome likewise upon a square plane, but the given axal rib at right angles to the side, is the segment of a circle less than a semi-circle.

Figure 3.—Plan of a polygonal dome, showing the covering extended, and the angle-rib. The method of finding the covering and angle-rib for *Figures* 2 and 3, is the same as in *Figure* 1, and may be described in the same words.

Instead of laying out the covering and angle-rib, as in *Figure* 3, of the octagonal dome, they may be laid down as in *Figure* 4, without laying down the whole plan; and if only the covering be wanted, it may be found without any part of the plan, as in *Figure* 5. Thus, let A D represent the middle of the boarding for one of the sides, and let A B, at right angles thereto, be half the breadth of the side A H, *Figure* 3; let A B, *Figure* 5, represent half the base of the rib; on A B describe a quadrant or similar figure to the given rib, I L K, *Figure* 5: make A D equal to the circumference, L K, of the given rib. The rule for this purpose will be found under those for measuring segments of circles; see the article SEGMENT; or if the arc be that of a quadrant, the quadrantal arc may be found, as in the article CIRCLE, and then taking a fourth part of the whole circle, or the half of a semi-circle. We shall here give examples both for a complete quadrant, and for a rib which is the half of a segment less than a semi-circle:

Figure 3.—Suppose the base, I L, to be 20 feet, then

$$\frac{3\frac{1}{7} \times 20}{2} = 31 \text{ feet } 5 \text{ inches.}$$

Again, suppose the base to be 12 feet, as before, but the height to be only 5 feet, then the whole chord will be 24 feet, and the versed sine 5 feet.

RULE.—Multiply the sum of six times the square of the half chord, and five times the square of the versed sine, by the chord; and divide the product by the sum of six times the square of the half chord and the square of the versed sine; and the quotient is the length of the arc, nearly.

Here the half chord is 12 feet: therefore,

$$\frac{(6 \times 12^2 + 5 \times 5^2) \times 24}{6 \times 12^2 + 5^2} = 26.69, \text{ the answer.}$$

Or thus, at full length:

then $6 \times 12^2 + 5^2 = 864 + 25 = 889.$

$$\begin{array}{r} 12 \\ 12 \\ \hline 144 = 12^2 \\ 6 \\ \hline 864 = 6 \times 12^2 \\ 125 \\ \hline 989 = 6 \times 12^2 + 5 \times 5^2 \end{array} \qquad \begin{array}{r} 5 \\ 5 \\ \hline 25 = 5^2 \\ 5 \\ \hline 125 = 5 \times 5^2 \end{array}$$

24 whole chord, or base of two ribs.

$$\begin{array}{r} 3956 \\ 1978 \\ \hline 889)\ 23736\ (26.63 \\ 1778\ \ 13.315 \\ \hline 5956 \\ 5334 \\ \hline 6220 \\ 5334 \\ \hline 8860 \\ 8001 \\ \hline 859 \end{array}$$

13.315 feet for the length of the curved hip.

NOTE.—The above rule is the invention of the author.

Figure 5.—Then making A D equal to the length of the arc, divide the curve B C into any number of equal parts, and draw the lines $e\,h$, $f\,i$, $g\,k$, parallel to B A, cutting A C at h, i, k; divide the straight line A D into as many equal parts as the curve B C is divided into, at the points l, m, n, and draw $l\,o$, $m\,p$, and $n\,q$, parallel also to A B; making $l\,o$, $m\,p$, $n\,q$, respectively equal to $h\,e$, $i\,f$, and $k\,g$, and through the points B, o, p, q, D, draw a curve; then the space comprehended between this curve and the straight lines A D and A B, will be half the covering of one of the sides.

Figure 6.—*Given* K L M N, *the plan of an oblong dome, and the rib* A B; *to find the hip and the rib parallel to the longitudinal side, also the covering upon the longitudinal and transverse sides.*

Divide the curve A B into any number of equal parts, at the points of division 1, 2, 3, and draw lines 1 k, 2 i, 3 h, parallel to N K, the longitudinal side cutting the seat of the hip K G: from the points of intersection in K G draw lines parallel to K L, the breadth of the dome, to the points m, n, o; draw G E parallel to N K, and produce it to F; also produce A C to D; take the parts of the given rib A B, and extend them on C D, from C to 1, from 1 to 2, from 2 to 3, and from 3 to D: make 1 m, 2 n, 3 o, on each side of C D, respectively equal to the parallel distances from A K, comprehended between the lines A G, and K G; from the points d, e, f, cut by the lines parallel to K L, make $d\,a$, $e\,b$, and $f\,c$, respectively equal to the several heights of the given rib A B, and trace a curve through the points E, a, b, c A: upon the straight line E F, extend the parts E a, $a\,b$, $b\,c$, c A, of the arc E A, from E to a, from a to b, from b to c, and from c to F; through the points a, b, c, in E F, draw $k\,k$, $i\,i$, $h\,h$, parallel to K L; make the parts $a\,k$, $b\,i$, $c\,h$, respectively equal to the parallels of E K, comprehended between E G and K G; then K F L, is the form of the boarding for each end, and L D M, that of the sides.

The angle-rib is found the same as in the square dome.

Figure 7, No. 1.—*To find the covering of an oblong polygonal dome.*

Given the plan A B C D E F G H I, and the axal section through its breadth, a semi-circle. Take any straight line, N Q, No. 2; in No. 1, draw lines from the middle point I, perpendicular to the sides G H, H A, A B, of the polygon, and let these perpendiculars be I K, I H, and I L: on the straight line M Q, No. 2, make M O equal to I K, M P equal to I H, and N Q equal to I L, No. 1. In No. 2, draw M N perpendicular to M O; from the centre M, with the radius M O, describe the quadrant O N: divide the arc O N into any number of equal parts, say four, $w\,z$, $z\,y$, $y\,x$, x N, at the points z, y, x; from the points x, y, z, No 2, draw lines $x\,u$, $y\,v$, $z\,w$, cutting M O at u, v, w; transfer the distances M u, $u\,v$, $v\,w$, w O, to the straight line I K, No. 1. Through the points of division, draw lines parallel to H G, to cut the diagonals G I, and H I; from the points of section in H I, draw lines parallel to H A, to cut the next diagonal A I: from the points of section in A I, draw lines parallel to A B, cutting B I: take the parts O z, $z\,y$, $y\,x$, x N, No. 2, and extend them to K R, No. 1, and draw lines through the points of section, parallel to H G; make the two parts of the lines so drawn on each side of K R, respectively equal to the lines drawn parallel to H G, terminated by K I, and H I. With the greater semi-axis M P, and lesser semi-axis M N, describe the quadrant of an ellipsis N P M: through the points z, y, x, draw lines parallel to M P, to cut the elliptic curve: extend the elliptic curve so cut, upon the straight line H S, and through the points of section, draw lines parallel to H A; transfer each of the lines contained between H I and A I, respectively, to each of the parallels on the other

side of H A; or draw lines through the several points of section in the diagonal A I, parallel to I S, to cut the lines perpendicular to H S, and the points of intersection will form the direction of the line for the edge of the covering H S A. In like manner, by describing the quadrant of the ellipsis M Q N, and by drawing lines through the points z, y, x, to cut the curve N Q, by proceeding as before, we shall obtain the covering A B T. The three coverings G R H, H S A, A T B, cover more than one-quarter of the whole, by the half coverings G R K, and L T B, of the side and end. The covering of each side so found answers to the opposite side, by turning the back for the front. Each covering, except that upon the side, and that upon the end, will cover four different sides: the covering upon the sides and ends only answer in two opposite places.

The angle-ribs of this dome are found as usual. If the circumference of each quadrant or rib perpendicular to the side, were ascertained by calculation, then the boarding could easily be laid out without the use of a plan, upon the same principle as in *Figure* 5, as is obvious from what has already been said.

To construct the ribs of a spherical dome, with eight axal ribs, and one purlin in the middle.

Plate II. *Figure* 1, No. 1.—Let A B C D E F G H, be the semi-plan, which is supposed to be divided into four equal parts, and let A H be the diameter, terminating the semi-plan; divide the semi-circumference into four equal parts, from the extremity A, to the other extremity H, of the diameter A H; and the points of division will mark the middle of the back, or convex sides of the ribs. This being the case, let B C c b, D E e d, F G g f, be the plans of the intermediate ribs, B C, D E, and F G, having the points of division in the middle; the lines B b, C c, D d, E e, F f, G g, being the places of the vertical sides, and parallel to the lines drawn from the middle of B C, D E, F G, to the centre. Draw V X, No. 2, parallel to A H, No. 1: from the side A a, B C c b, D E e d, &c., draw lines cutting V X, perpendicular to A H; then taking V X for the under side of the kirb or wall-plate, draw its proper thickness. In the elevation, No. 2, of the dome, the front ribs are quadrants, forming a semi-circle with the upper side of the wall-plate, which is of course the diameter; the curves of the sides of each of the other ribs are the quadrants of an ellipsis of the same height with the front rib, and their projected places, from the plan upon the kirb V X, gives the lesser semi-axis. To form the purlins, place the section of one of them in its situation, and, circumscribing its angles, draw the square m n o p, draw m q, and n r, parallel to V X, and the lines from the several angles of the purlins, also parallel to V X; then, where they cut the opposite rib Y X form the section of the purlin, and then the circumscribing square q r s t. First form a ring, whose greater diameter is m q, or n r, and whose inner, or less diameter, is p t, or o s, and whose thickness is m n, or p o; the ring being thus formed, gauge lines from each of the sides, as is shown by the section; then cut off the angles made by the horizontal and perpendicular surfaces, between each two lines, on each two adjoining sides, and the purlin will be formed. The ribs of this dome are not complete quadrants, as they abut upon the upper kirb W Y at the top.

The method of covering this dome is, to suppose the surface polygonal; the principle is the same as is shown in *Plate* III.

Figure 2.—The ribs of an elliptic dome are formed in the same manner as in *Figure* 1, and the covering as in the preceding Plate; the covering of one quarter being found, answers for the whole, as has been observed. It may be noticed, once for all, as a general rule to cover any dome, divide a quadrant of the plan into as many equal parts as there are to be boards in each quarter, then draw lines from the points of section, to the centre of the plan, and draw chords by joining each two adjacent points, so that there will be as many triangles formed as there are boards: from the centre of the plan, draw a perpendicular to each of the chords, meeting each chord; make the length of each perpendicular the base of a rib, and take the common height of the dome as the height of each rib, and place it at the extremity, at right angles to each base; and describe the quadrant of a circle or ellipsis, according as the base and height may be equal, or unequal. To find the covering for any side, divide the curve of the upper side of the rib, so found, into any number of equal parts, and draw lines perpendicular to the base to intersect therewith, and the whole will be completed, as shown in *Plate* III.

No. 6, shows the covering over I O N; No. 7, over I N M; No. 4, the middle rib; No. 5, the rib between the side and end ribs.

To find the solidity of a square dome, the axal sections through the middle of the sides being semi-circles.

Let the radius of the circle be represented by r; suppose then, in the vertical section, that we draw any line parallel to the base, for the section of the generating plane, which is equal to the side of the generating square. Suppose the axis to be drawn upon the section, and the part of the axis from the summit to the generating line, to be denoted by x and y, to denote the half generating line, we shall then have, by the property of the circle, $y = (2\,r\,x - x^2)^{\frac{1}{2}}$, and consequently $2\,y = 2\,(2\,r\,x - x^2)^{\frac{1}{2}}$ the whole length of the side of the generating square.

Therefore, $4\,y^2 = 4\,(2\,r\,x - x^2)$

and $4\,y^2\,\dot{x} = 4\,\dot{x}\,(2\,r\,\dot{x} - x^2)$ the fluxion of the solid. The fluent of $4\,y^2\,\dot{x} = 4\,r\,x^2 - \dfrac{4\,x^3}{3}$ for the solidity of the segment of the dome. Now, therefore, if the solidity of the whole dome be required, it is only supposing x to become equal to r; we then find $4\,r\,x^2 - \dfrac{4\,x^3}{3} = 4\,r^3 - \dfrac{4\,r^3}{3} = \dfrac{8\,r^3}{3}$. Suppose $d =$ the diameter, equal to $2\,r$, and $a = r$, the altitude, then will $\dfrac{8\,r^3}{3} = \dfrac{2\,d^2 a}{3}$, that is, the solidity of the dome is equal to two-thirds of the circumscribing rectangular prism. If in the above dome all the horizontal sections had been circles instead of squares, the dome would have been spherical; let us suppose that $p = .7854$, the area of a circle, the diameter of which is unity, then in the case of the segment of the sphere we have $p\left(4\,r\,x^2 - \dfrac{4\,x^3}{3}\right)$ for the solidity of the dome when less than a hemisphere; or, putting $2\,r = d$, and a equal to the altitude of the segment, then $\left(4\,r\,x^2 - \dfrac{4\,x^3}{3}\right) = p\left(2\,d\,a^2 - \dfrac{4\,x^3}{3}\right)$ and the hemispheric solidity is $p\,\dfrac{2\,d^2\,a}{3}$. The same form of expression may be shown for all polygonal domes whatever: it is only using a proper multiplier for p, when the radius of its circumscribing circle is unity.

Suppose it were required to find the solidity of a trun

cated hemispheric dome, let $x =$ the altitude of the dome, as before, then, by the nature of the circle, we have

$y^2 = r^2 - x^2$ equal to one quarter of the generating square.
$4\,y^2 = 4\,r^2 - 4\,x^2$ for the generating square.
$4\,y^2\,x = 4\,r^2\,x - 4\,x^2\,x$ the fluxion of the solid.

The fluent of $4\,y^2\,x = 4\,r^2x - \dfrac{4\,x^3}{3}$: now let $d =$ the diameter equal $2\,r$, and a equal the altitude of the dome, then $4\,r^2\,x - \dfrac{4\,x^3}{3} = d^2\,a\,\dfrac{4\,a^3}{3}$ equal to the solidity of the square truncated dome, and $p\left(d^2\,a - \dfrac{4\,a^2}{3}\right)$ equal the solidity of the circular dome. Let us suppose the same expression to be applied to a hemispheric dome,

then $p\left(d^2\,a - \dfrac{4\,a^3}{3}\right) = p\left(d^2\,r = \dfrac{4\,r^3}{3}\right)$

$= p\left(d^2\,r - \dfrac{d^2\,r}{3}\right) = p\,\dfrac{2\,d^2\,r}{3} = p\,\dfrac{2\,d^2\,a}{3}$, the same formula as above.

Practical application of the preceding rules.

To find the solidity of a dome less than a hemisphere, upon a square plan, when its axal sections, parallel to the sides, are circles.

From twice the diameter of the vertical section multiplied into the square of the altitude, subtract the third part of four times the cube of the altitude, and the remainder is the solidity of the square segmental dome.

Example.—Suppose the altitude of the dome to be 4 feet, and the diameter of the vertical section 20 feet, the solidity of the dome is required.

20	4
2	4
40 twice the diameter of the vertical section.	16 square of the [altitude.
16	4
640	4
$85\frac{1}{3}$	16
$554\frac{2}{3}$ solidity required of the square dome.	4
	64
	4
	3)256
	$85\frac{1}{3}$

Suppose now a circular dome of the same dimensions: Then

.7854
$554\frac{2}{3}$
31416
39270
39270
435.1116
2618
2618
435.6352 feet, the solidity required.

To find the solidity of a truncated square dome, the axal section being that part of a semi-circle left by cutting off a segment parallel to the diameter.

From the square of the side of the base, multiplied into the altitude of the dome, subtract the third part of four times the cube of the altitude, and the remainder is the solidity required.

Example.—Suppose the side of the base 20 feet, and the altitude 6 feet, what is the solidity?

20	6
20	6
400	36
6	6
2400	216
288	4
2112 solidity of the dome required.	3)864
	288

But if the horizontal sections had been circles instead of squares, we should then have the solidity of the circular dome as follows:

2112
.7854
8448
10560
16896
14784
1658.7648 the solidity of the dome when the horizontal sections are circular.

It may here be remarked, that the segment and truncated domes make together a complete square dome, each side of the base being 20 feet, and the altitude 10 feet.

Now the solidity of the segment dome is $554\frac{2}{3}$ feet.
and that of the truncated dome . . . 2112
Therefore the whole square dome whose vertical section is a semi-circle, is . . $2666\frac{2}{3}$

Now, the rule for measuring a square dome with semi-circular vertical sections parallel to the sides of the base, is to take two-thirds of the area of the base, multiplied into the height:

20
20
400 area of the base
10
3)4000
$1333\frac{1}{3}$
$1333\frac{1}{3}$
$2666\frac{2}{3}$ the solidity, as before.

But as it may be objected by many, that, when a square or circular dome, whose vertical section is the segment of a circle, is required to find its solidity, it is difficult to find the diameter of the vertical section, and that it would be more eligible to find the solidity from the side or diameter of its base, and the altitude of the section: in order to save the trouble of finding the diameter, we shall here show the investigation of another rule, independent of any foreign or adventitious dimension.

Let s equal the side of the square base,

then $\frac{s}{2}$ is equal to half the side of the base;

and if d be the diameter of the section, and a its altitude, then, by the property of the circle,

$$\frac{s^2}{4} = a\,(d - a) = d\,a - a^2$$

$$\text{therefore, } d\,a = \frac{s^2}{4} + a^2$$

$$\text{consequently, } d = \frac{s^2}{4a} + a$$

$$\text{and } 2\,d = \frac{s^2}{2a} + 2\,a$$

Therefore, by substituting $\frac{s^2}{2a} + 2\,a$ for $2\,d$ in the formula $2\,d\,a^2 - \frac{4a^3}{3}$, we obtain $\frac{as^2}{2} + \frac{2a^3}{3}$ for the solidity of the segmental dome, independent of the diameter of the section.

This rule may be expressed thus:

To half the area of the square base, multiplied into the altitude, add two-thirds of the cube of the altitude, and the sum will be the solidity of the dome.

Let us take the same example as at first, and we shall find the side of the square of the base to be 16 feet: therefore,

```
    16                          4
    16                          4
   ----                        ---
    96                         16
   16                           4
   ----                        ---
   256 square of the base.     64 cube of the altitude.
     4 altitude.                2
   ----                        ---
 2)1024                      3)128
   ----                        ---
   512                         42⅔
    42⅔                        ---
   ----
   554⅔ cubic feet, as before, in the segmental dome.
```

The solidity of any dome whatever may be found by the following general rule:

To the areas of the two ends, add four times the area in the middle; then, one-sixth of the sum multiplied by the altitude, gives the solid contents. This rule applies to all domes whose vertical section is contained between any two opposite arcs of the same circle, and two parallel lines, and will even apply to those domes which are the segment of a sphere. In the seccond example, the side of the square of the base being 20, and of the top 16, the middle area will be found to be 364.

```
  20                     16                 364
  20                     16                   4
 ----                    --                ----
 400 area of base.       96                1456
                        16                  256
                        ----                400
                        256 area of top.   ----
                                           2112 solidity.
```

Because multiplying and dividing by 6, gives the same number.

To find the solidity of a hollow square truncated dome, the shell being of equal thickness, supposing each edge of the base equal to the diameter of the circle of which the section is a part.

We found before, supposing d = the side of the square base, and a equal the altitude, that the solidity of the solid dome was expressed by $d^2\,a - \frac{4a^3}{3}$, then to find the solidity of the shell, it is only finding the solidity of two solid domes, of the same altitude, but of different dimensions at the base, and deducting the greater from the less.

Now let D be the side of the base to the external surface, and d the side of the base corresponding to the internal surface; then the solidity of the solid comprehended within the external surface, and the two parallel planes forming the end, is $D^2\,a - \frac{4a^3}{3}$:

In like manner, the solidity of the solid which would fill the cavity, is $d^2\,a - \frac{4a^3}{3}$;

then, by subtracting the latter of these expressions from the former, we obtain $D^2\,a - d^2\,a = a\,(D^2 - d^2)$ for the solidity of the shell.

This rule may be thus expressed in words:

Multiply the difference of the areas of the bases by the altitude of the dome, and the product will give the solidity of the shell.

Example.—Suppose the side of the base, between the external convex surface, to be 20 feet, and the side of the base of the internal cavity, or bason, to be 18 feet, the solidity of the shell is required.

```
  18     20
  18     20
 ----   ----
 144    400 area of the base contained between the convex surface.
 18     324 area of the base contained between the concave
 ----   ----    surface.
 324     76 difference of the areas of the bases.
          6
        ----
        456 solidity of the shell, as required.
```

To find the convex surface of a dome.

Let the diameter $BG = d$

$BA = x$

and $CA = y$

$BC = z$

we have, by similar triangles,

AOC and CED, CA : CO : : CE : CD

that is, $y : \frac{d}{2} : : \dot{x} : \dot{z} = \frac{d\dot{x}}{2y}$:

but since the fluxion of the surface whose sections are circular is denoted by $2\,p\,y\,\dot{z}$, where p is equal to 3.1416;

therefore, we have $2\,p\,y\,\dot{z} = p\,d\,\dot{x}$

and the fluent of $2\,p\,y\,z = p\,d\,x$: therefore, the superficies of the segment of a hemispheric dome is equal to the convex surface of a cylinder of the same altitude, and of a diameter equal to the diameter of a great circle of the sphere; now, when the segment becomes a hemisphere, then $p\,d\,x = \frac{pd^2}{2}$, but since $p = 4 \times .7854$, we shall have $\frac{pd^2}{2} = 2 \times .7854d^2$; that is, the convex area of the hemispheric dome is double the area of its base; and since the area of any segmental dome is the same as that of a cylinder of the same altitude, and of a diameter equal to that of its great circle; it follows also, that the convex surface of any truncated dome is equal to the surface of a cylinder of the same altitude, and of a diameter equal to the great circle of the sphere.

To find the convex surface of the segment of a dome, independent of the diameter of the great circle.

Let D = the diameter of the great circle,
a = the altitude of the dome,
d = the diameter of the base of the dome;

then, by the property of the circle, $\text{D}\,a - a^2 = \frac{d^2}{4}$,

therefore $\text{D} = a + \frac{d^2}{4a}$,

But $p\,\text{D}\,a$ is equal to the convex surface; therefore

$p\,\text{D}\,a = p\,a^2 + \frac{pd^2}{4}$ = the area of the convex surface $= p\left(a^2 + \frac{d^2}{4}\right)$. Therefore,

To find the area of the segment of a dome:

Multiply the sum of the square of the altitude and the fourth part of the square of the diameter of the base, by 3.1416, and the product will be the superficies of the dome.

Example.—What is the superficies of the segment of a dome, the diameter of the base being 17.25 feet, and the height 4.5 feet?

```
      17.25                         4.5
      17.25                         4.5
     ------                        ----
       8625                         225
      3450                         180
     12075                         -----
     1725                          20.25
    --------
  4 )297.5625
    ---------                       [base's diameter.
     74.3906  the fourth part of the square of the
     20.25    square of the altitude.
    --------
     94.6406  the sum.
      3.1416
    --------
     5678436
     946406
    3785624
    946406
   2839218
   ------------
   297.32290896 feet, the surface required.
```

To show that the superficies of any portion of a sphere, contained between any two parallel planes, is equal to the product of a circumference of a great circle into the distance of the parallel planes; that is, equal to the surface of a cylinder, the base of which is equal to the great circle of the sphere, and the altitude equal to the distance of the parallel planes:

Let A equal the altitude of the segment of the sphere, including both the altitude of the segment wanting, and the distance of the parallel planes; also, let a equal the altitude of the segment wanting; and let c be the circumference of the great circle.

Then, whether the segment include the part contained between the parallel planes, or be the segment cut off, the area of the curved surface will still be expressed by the product under the circumference of the great circle and the height of the segment; therefore, $c\,\text{A}$ is equal to the superficies of the segment, including that of the solid contained between the two parallel planes; also, $c\,a$ is the superficies of the segment cut off; but the difference between the areas of the curved surfaces of these two segments is equal to the curved surface of the solid contained between the two parallel planes; therefore, $c\,\text{A} - c\,a = c(\text{A} - a)$ is the surface of the sphere contained between the parallel planes.

It would, however, be very desirable to have another substitute in terms of the upper and lower diameter of the solid, in place of the diameter of a great circle; for this purpose, we shall here give the following rules:

Given any two parallel chords in a circle, and their distance, to find the distance of the greater chord from the centre.

To the square of the distance between the chords add the square of half the lesser chord. The difference between this sum and the square of half the greater chord, divided by twice the distance of the chords, gives the distance from the greater chord to the centre.

Example.—Suppose the greater chord, C D, is 48 feet, and the lesser, A B, 30 feet, and their distance, E G, 13 feet; what is the distance, E F, from the centre to the greater chord, C D?

```
 13     30 = 15                     48 = 24
 13     --   15                     --   24
----     2                           2
 39          ----                       ----
13            75                         96
----         15                         48
169          ----           [chord.     ----           [chord.
             225 square of the less    576 square of greater
             169 square of distance.   394
             ----                      ----
             394                   26) 182 (7 dist. required.
                                       182
```

Given the chord of a circle, and its distance from the centre, to find the radius of the circle.

To the square of the half chord, add the square of the distance from the centre, and the square root of the sum will be the radius required.

Example.—Given the chord C D, 48 feet, and its distance E F from the centre, 7 feet, the radius of the circle is required.

```
 48 = 24              7 × 7 = 49
 --   24
  2
     ----
      96
     48
     ----
     576
      49
     ----
     625 (25 the radius required.
     4
     ----
 45) 225
     225
```

Suppose, then, that we would wish to obtain the area of the curved surface of a dome, contained between two parallel planes, the greater of which is 30 feet diameter, and the lesser 20 feet diameter, and the distance between them being 5 feet.

```
10 × 10 = 100          15 × 15 = 225
 5 ×  5 =  25                    125
         -----                  -----
          125            1,0) 10,0 the difference.
                               10. feet,
```

the distance of the greater chord from the centre.

$(15)^2 = 225$
$(10)^2 = 100$

325 (18.02 the radius of the circle
1

28) 225
224

3602) . . 10000
7204

.2796

Say then, that the diameter is 36 feet, omitting the very small fractional part .02.

Then $36 \times 3.1416 = 113.976$ the circumference of a great circle.

Therefore $113.976 \times 5 = 569.880$ feet, the superficial content of the dome.

Figure 2.—In order to show the truth of the above rule, for finding the above diameter of a circle, from the two chords, and the distance between them being given;

Let $y =$ F I, the height of the lesser segment;
$h =$ F B, the distance between the chords;
$x =$ B D, the distance from the nearest chord A G, to the centre I;
$\text{C} =$ A B, half the greater chord A G;
$c =$ E F, half the lesser chord;

Then, by the property of the circle, we have

$$\text{FI} \times \text{FK} = \overline{\text{EF}}^2 = c^2$$
$$\text{and} \quad \text{BI} \times \text{BK} = \overline{\text{BA}}^2 = \text{C}^2$$
$$\text{But} \quad \text{FI} = y$$
$$\text{and} \quad \text{FK} = y + 2x + 2h$$
$$\text{also} \quad \text{BI} = y + h$$
$$\text{and} \quad \text{BK} = y + h + 2x.$$

Therefore $y \times (y + 2x + 2h) = c^2$ first equation;
$(y + h) \times (y + h + 2x) = \text{C}^2$ the second equation;
$y^2 + 2xy + 2hy = c^2$, the first actually multiplied;
$y^2 + hy + 2xy + hy + h^2 + 2hx = \text{C}^2$, the second multiplied.

Then by putting n in the place of $x + h$ in each of these equations,
the first becomes $y^2 + 2ny = c^2$
and the second $y^2 + 2ny + 2hx = \text{C}^2 - h^2$

$y^2 + 2ny + n^2 = c^2 + n^2$ by completing the square of the first. Therefore
first value of $y = (c^2 + n^2)\frac{1}{2} - n$

$y^2 + 2ny = \text{C}^2 - h^2 - 2hx$ second transposed;
therefore $y^2 + 2ny + n^2 = \text{C}^2 - h^2 - 2hx + n^2$
$y + n = (\text{C}^2 - h^2 - 2hx + n^2)\frac{1}{2}$; the second
value of $y = (\text{C}^2 - h^2 - 2hx + n^2)\frac{1}{2} - n.$

Then by making the first and second value of y equal to each other, and by taking away the negative quantity $-n$, which is common to both sides, and squaring the equation, we obtain

$$c^2 + n^2 = \text{C}^2 - h^2 - 2hx + n^2$$
$$\text{or} \quad c^2 = \text{C}^2 - h^2 - 2hx$$
$$\text{or} \; 2hx = \text{C}^2 - c^2 - h^2$$

$$\text{and consequently } x = \frac{\text{C}^2 - c^2 - h^2}{2h} = \frac{\text{C}^2 - (h^2 + c^2)}{2h}$$

which expression agrees with the rule.

The second rule for finding the radius of the circle, is only to find the hypothenuse of a right-angled triangle: the two sides containing the right angle being given, the square of the hypothenuse is equal to the sum of the squares of the two sides by the 47th Proposition of Euclid.

DOMESTIC ARCHITECTURE, that department of the art which relates especially to the design and erection of edifices adapted to private purposes as distinguished from those erected for public uses, more particularly of such as are employed as private dwellings. Although holding an inferior position in the scale when compared with other branches of the art, domestic architecture is of sufficient importance at the present day to merit the greatest attention of the professional man. Amongst the ancients this department held a very low position, all the energies of the architect being employed on the public buildings and temples. Such a term would scarcely have been understood amongst the Greeks and Egyptians, and but little amongst the earlier Romans, their private dwellings scarcely deserving the name of buildings. As luxury increased at Rome, the houses of private individuals increased in size and magnificence, as well as in accommodation, and the country-residences of the higher classes seem to have been buildings of some importance; Pliny's villa contained thirty-seven apartments on the ground-floor. Specimens of Roman houses exist at Herculaneum and Pompeii, as well as some few elsewhere. There is a villa at Bignor in Sussex, which contains 74 rooms, and covers an area 630 feet in length, by 335 feet in breadth.

Of English Domestic architecture, we need say little in this place; the term can scarcely be applied to any habitable buildings erected previous to the reign of Henry VII., and the buildings of this date will be dilated upon when treating of the style known, after the name of the reigning family, as the Tudor style. Up to the period in which this style prevailed, all the larger residences in England were fortified more or less. For an account of the earlier of these edifices we refer to CASTLES. *See* also HOUSE, TUDOR or ELIZABETHAN ARCHITECTURE, VILLA, ROMAN ARCHITECTURE, &c.

DOMICIL, or DOMICILE, (*domicilium*, a mansion), in general, the place of residence of an individual or family; in a more restricted sense, where a person resides only for a time.

DONJON, or DONGEON, the principal tower of a castle usually raised on a natural or artificial mound, in the innermost court or ballium. Its lower part was used as a prison, and it was frequently called the donjon-keep. Hence the modern term dungeon.

DOOKS, pieces of wood, about nine inches in length, inserted in stone or brick walls; the term is used in Scotland, and is of the same import with the London term, *plugs*, or *wood bricks*.

DOOR, (from the Saxon *dor*), the gate of a house, or the passage into an edifice, apartment, &c.

The construction of doors naturally divides itself into two branches, viz., the formation and proportion of the aperture, or opening, which, in outer walls, belong to the mason or bricklayer; and framing of the gate or leaf, by which the entrance is to be secured, together with its appurtenances, which appertains to the joiner's department.

The proportion of the aperture must always be according to the size and intention of the building, and should be attended to above every other consideration: in general the dimensions may be in the ratio of one to two, for large doors, and from three to seven in those of less size.

Entrances are of two kinds; doors and gates. The former are used only for the passage of persons on foot; the latter admit horsemen and carriages. Doors are used for churches,

public edifices, dwelling-houses, and apartments: gates serve as inlets to cities, fortresses, parks, gardens, &c. Apertures of gates, being always wide, are usually arched; while the figure of doors is generally a parallelogram.

According to Vitruvius, the hypothyron, or aperture for doors, should be as follows:—"The height from the pavement to the ceiling of the temple being divided into three parts and a half, two of the whole parts were allowed for the height of the door. These two parts were subdivided into twelve smaller parts, of which five and a half were allowed as the width of the door at the base; and the upper part was contracted according to the following rules: if not more than 16 feet high, the contraction was one-third of the width of the jamb on the face; if the height was more than 16 and not more than 25 feet, a fourth part of the width of the jamb only was employed; and from beyond 25 feet, and not exceeding 30 feet, one-eighth only."—*Vitruvius*, book iv.

Public buildings, palaces, and noblemen's mansions, where a great concourse of company may be expected, should have doors of much greater dimensions than those of buildings of inferior rank; from six to twelve feet may be taken for the width of the outer entrance, and from four to six feet for those in the interior; in private houses, the latter, if they have but one leaf, should never be more than three feet and a half in breadth, nor less than that of the windows. In all cases their height should be proportioned to that of the story in which they are placed, except where they are used for laying two apartments into one; in which case they will be of a height less than double the width.

Vitruvius, as we have before observed, has prescribed rules for Attic, Ionic, and Doric doors, all of which have their apertures wider at the bottom than at the top; examples of this shape may be seen in the ruins of the temple of Minerva Polias at Athens, the temple of Vesta at Tivoli, and in other Greek and Roman remains. These doors possess the advantage of shutting themselves, to which they probably owe their invention; and they may be conveniently adopted in modern houses, as they rise in opening, and will clear a carpet, though when shut, they go close down upon the floor.

The principal entrance to a building of any magnitude should be in the centre, as productive of the greater symmetry of appearance, and as communicating more readily with the various apartments of the interior. In the principal rooms, the door should be two feet, at least, from the return of the wall, to admit of furniture being placed close up in the corner.

The lintels of exterior doors should always range with those of the windows. Apertures placed in blank arcades, are usually placed at the same height as the springing of the arch: when they have dressings, the head of the architrave, or cornice, is generally on the level of the impost.

The decorations of a door-way commonly consist either of an architrave surrounding it, with or without a cornice, or with a complete entablature: consoles are sometimes introduced, flanking the architrave jambs, and supporting the ends of the cornice. When the architrave jambs are flanked with pilasters, whether of the orders, or of some emblematical form, the projections of their bases and capitals are always less than that of the surrounding architrave, and the architrave over the capitals is similar to that over the door itself. Doors are sometimes decorated with one of the five orders, and in very considerable buildings, the entrance is adorned with a portico, so as to resemble an ancient Grecian temple.

In embellishing the piers of gates, or outer doors, it should be remembered, as a general rule, that as the pier is itself only an inferior building, it should never be richer than the front of the house. As for instance, where the front of the latter is ornamented with Doric columns, the Ionic should not be found in the piers; and it would be better to omit columns altogether, than use the Tuscan order for piers in any case. If the Ionic or Corinthian orders be used in the front of the house, the Doric or Ionic may be with propriety introduced in the piers. Niches are almost always introduced into piers, for which reason the columns do better on pedestals, because the continued moulding from their cap forms an agreeable ornament under the niche.

The wooden closures by which the apertures are opened or closed, come within the province of the joiner: these are properly the doors, and are either framed, battened, or ledged, as described in the following articles. In ordinary, and even in good houses, frequently, the doors are of deal; in noblemen's mansions, they are often of mahogany, solid or veneered, and sometimes of wainscot, especially when the building is in the antique style. Apartments reserved for the reception of money, plate, jewels, &c. are usually secured with iron doors; and in the descriptions of ancient temples, we read of doors of ivory, brass, silver, and gold.

Door, *Baize*, the inner door of an apartment, covered with baize for securing the room from the influx of the cold air.

Doors, *Batten*, though formerly much in use, are now confined to buildings in the pointed style of architecture. They consist of boards glued together, to the size of the aperture, with styles, rails, and munnions, made of battens, nailed upon them, so as to give the appearance of a framed door. This may be done, either on one or both sides; and the door is accordingly denominated single or double battened. The vertical joints should be hid by the munnions of the framing; and the latter, instead of being glued, should be bolted through to a framing behind, which will make them very strong. The large gates and doors of ancient British edifices are thus constructed. The practice of imitating the framing of Grecian and Roman doors, is not, however, to be recommended in modern times, especially if no bolts be used: for the stuff, however well seasoned, will be subject to the influence of the atmosphere, and shrink or swell, as the air is dry or damp. It is scarcely necessary to remark, that this evil will be enhanced in proportion as the wood is less seasoned.

Doors, *Framed*, which are either single, folding, double, or double margin, are employed in all descriptions of buildings, and consist of styles, rails, panels, and, in most cases, of munnions also. The framing includes all the parts but the panels, and is held together with mortices and tenons. The styles are the vertical parts of the framing at the sides. The rails are the horizontal pieces, tenoned into the styles. Munnions are parts of the framing, tenoned into the rails. The panels fill up the holes left in putting the framing together, and are let into grooves cut in the internal edges of the styles, rails, and munnions. Doors are generally framed in rectangular compartments; though other forms, as circles, ellipses, lozenges, &c. may be adopted, according to the fancy of the proprietor, or the taste of the builder. Framed doors are either square or moulded; the former are used only in common houses. Mouldings are of various forms, some confined within the framing, and others projecting beyond it. The mouldings and form of the panels of the door, generally regulate those of the window-shutters.

Folding doors, or *doors of communication*, are made in two breadths, and have a pair of styles to each leaf.

The Building Act (7 and 8 Vict. cap. 84) requires that openings through party walls be secured by wrought-iron doors.

"Such openings must not be made wider than six feet, nor higher than eight feet, unless in each case, and upon special evidence of necessity for convenience or otherwise, the official referees shall previously authorize larger openings.

"And the floor, and the jambs, and the head of every such opening, must be composed of brick or stone, or iron work throughout the whole thickness of the wall.

"And every such opening must have a strong wrought-iron door on each side of the party wall, fitted and hung to such opening without wood-work of any kind; and such doors must not be less than one-fourth of an inch thick in the panels thereof.

"And each of such doors must be distant from the other not less than the full thickness of the party wall."

Double doors are contrived to close against each other, in opposite directions, the one opening outwards, the other going inwards, in order to keep the apartment warm: the inner door being generally covered with baize.

Double margin doors, are single doors, with a broad piece running vertically down the middle, called the *staff-style*, imitating the two internal styles of folding doors when shut.

Whatever kind of door be adopted, it should, for the sake of uniformity, be used in all the apartments of the same story.

Farther particulars may be seen under ARCHITRAVE, and JOINERY.

The term *door* is sometimes applied to the gates of locks or sluices.

DOORWAY, the entrance or aperture in which the door is hung. Doorways are usually rectangular in shape, but sometimes arched. In the early styles previous to the introduction of the arch, all apertures consisted by necessity of an horizontal lintel supported by two vertical jambs, although not unfrequently the jambs inclined converging upwards. Doorways were enriched in a variety of ways, often by a platband running round the jambs and lintel, and sometimes by an entablature above the lintel. An elaborate work upon the subject has been published by Professor Donaldson.

Soon after the introduction of the arch, that form was applied to doorways, the form of the arch, whether semicircular, pointed, or otherwise, being determined by the date and style of the building. Of the first form, the Romanesque style affords us some very beautiful specimens; witness that of the Temple Church, London, which is a very fine example, and consists of a compound arch, that is to say, a series of concentric and receding arches, each arch with its pier being profusely adorned with pillars and enriched mouldings of all kinds. These doorways seem to have been admired in all ages, for frequently, when all the rest of a church has been pulled down to make room for one of a more elaborate or more fashionable style of architecture, the old Romanesque doorway has been preserved, and worked up in the new structure. For exquisite examples of doorways in the pointed styles, we have only to refer to the magnificent western entrances of the Continental cathedrals, and the smaller and less elaborate, though not less beautiful, examples in our own country.

DOORWAY-PLANE, a term sometimes applied to the space between the doorway properly so called, and the larger door archway within which it is placed. This space is frequently ornamented with sculpture, &c.

DORIC ORDER, the most ancient Grecian order of architecture, was first used in building the temple of Juno at Argos, at the period when Dorus, father of the Dorians, reigned in the Peloponnesus; though, according to Vitruvius, its symmetry and proportions were not fixed till Ion, the nephew of Dorus, and chief of the Ionians, led an Athenian colony into that part of Asia Minor which was afterwards distinguished by his name, and there built a temple, after the fashion of those in the Dorian states, the columns of which were six diameters in height, taking the proportion from the ratio that a man's foot bears to the height of his body.

The Doric is distinguished, in general appearance, from the succeeding orders, by its bold and massy proportions, as well as by its comparative want of ornamentation; all its parts are bold and prominent, its details few and imposing.

Its origin is stated by Vitruvius to have been derived from the primitive buildings of the Greeks, which were made of timber; but others derive the style from the stone structures of Egypt, and others from those of Persia and the East. It would be the more natural method to discuss this subject ere proceeding farther, but as the discussion could not be readily understood without some previous acquaintance with the details and general character of the order, it may be as well to turn our attention to these matters first of all.

This order then consists, like the others, of column and entablature, but differs from them in this, that the first mentioned division comprises only two members, the shaft and capital; the base, which is indispensable in the other orders, being omitted in this, at least in the earlier and purer examples, as practised by the Greeks. The reason of this omission has been accounted for in various ways by different writers; Vitruvius will have it, that the base was first introduced in the Ionic order to represent the sandal or covering of a woman's foot, and that in the Doric, which resembled in some way or other a strong muscular and barefooted man, this member was not appropriate. Some are of opinion that the omission was occasioned by the close proximity of the columns in this order, which would not admit of any excrescence at the base. It is true the intercolumniation is very contracted, and the addition of any base, especially of a square one with its angular corners, would render the passage between the columns extremely narrow and inconvenient; indeed, even without a base, the space was inconveniently small, and was felt to be so, as we gather from the fact that the intercolumniation of the portico opposite the entrance-door was increased in width, evidently to afford readier access to the interior; notwithstanding, we can scarcely bring ourselves to conclude that this was the reason of the absence of a base. We rather incline to believe that a base had as yet never been thought of, the idea had not yet suggested itself; in Egyptian temples, from which we believe the Doric order to have emanated, the columns were usually devoid of bases, and it is but reasonable to presume that in their earlier essays, the Greeks aimed at nothing more than a copy, and did not think either of addition or improvement.

The Doric shaft then rises immediately from the platform on which the building stands, but this platform was usually raised on a series of three or more steps or gradations, the risers of which are proportioned not to the capacity of the human step, but to the magnitude of the building. The shaft, when compared with those of the other orders, is of stunted and massy proportions, its height being only 5 or 6 times greater than its lower diameter; the upper diameter, however, is of much smaller dimensions, the column converging rapidly towards the capital, a circumstance which gives an appearance of great stability. Towards the top of the column, a narrow channel is carved out round the shaft, so as to form an annulus in recession, and this marks the division between the shaft and capital, although a portion above this is in form nothing more than a continuation

of the shaft. The shaft was almost universally fluted, very few exceptions to the contrary existing; the number of the flutes is either 16 or 20, and their profile is that of a segment of a circle less than a semi-circle, being much broader and flatter or shallower than those of the succeeding orders. These flutes meet each other in a sharp arris, without the intervention of fillets, which are universal in the later orders; a slight fillet, however, is to be found in examples at Eleusis, Sermium, Rhamnus and Thoricus, but so narrow as to be insignificant. Much pains have been taken by various authors to account for the introduction and use of those flutes, but in our opinion without success; one supposes that they are imitations of the crevices in the stems of the trees out of which the timber-huts, the primitive models of the stone structures, were constructed; another, that the idea was occasioned by the rain-streak running down the shafts of the columns; and a third, that flutings were hollowed out for the purpose of resting spars in the crevices. Such hypotheses are doubtless very ingenious, although not to all minds equally convincing; for our own part, we do not see the absolute necessity there is to account for the reason and origin of every small member or ornamental detail. We require no further reason for the use of flutes, beyond the effect produced by them as a means of decoration, and as such we think their origin very easily accounted for. In the majority of Egyptian examples, from which—to prejudge the question—we suppose those of Greece to have been derived, the columns were reeded, or ornamented with projecting staves instead of recessed flutes; nor are the two methods of decoration so dissimilar and unconnected, for we have only to remove the staves to produce the flutes: and besides these methods we find another, in which the columns are what is called canted, that is to say, have their horizontal sections rectilineal polygons, the faces of the polygon or sides of the column being flat, instead of convex or concave. Thus we have three kinds of polygonal columns, the first of which seems to possess the primitive form, and the others to be merely enriched variations of the same. At Amada in Nubia, there is a very curious illustration of the progress made in the improvement and enrichment of columns, where in the same building we find one column a mere pier or simple parallelopiped, and another and adjoining one both rounded off at the corners and fluted; this last bears a remarkable resemblance to the Grecian Doric, on which account we shall have to refer to the subject again ere the close of this article. Specimens of Doric canted columns are to be found in the portico of Philip, king of Macedon, and in the temple of Cora; the flutes, however, are the most prevalent, as they are the most beautiful means of enrichment; the pleasing effect produced by them is attributable mainly to the diversity of light and shade so created, but this is not their only advantage; they likewise give a variety and lightness of appearance to the column, which would otherwise appear heavy, and at the same time, by the diminution of the breadth of the channels as viewed by the eye, add to the apparent circularity of the column. We have no specimens of reeded columns in this order. The flutes diminish in width as they reach the top of the shaft, to correspond with the diminution of the shaft; they are carried above the necking of the capital, and usually terminate immediately below the annulets, butting upon a plane surface perpendicular to the axis of the columns, or parallel to the horizon, as in the Propylæa at Athens. In other cases, as in the temples of Theseus and of Minerva at Athens, as well as in the Portico of Philip, in the island of Delos, the upper ends of the flutes terminate upon the superficies of a cone, immediately under the annulets, in a tangent to the bottom of the curve of the echinus of the capital. The same kind of termination takes place in the temple of Apollo, at Cora, in Italy; but in this example, the conic termination of the flutes is not immediately under the abacus, but at a small distance down the shaft, leaving a small portion quite a plain cylinder, and thus forming the hypotrachelium or neck of the capital. Palladio and other Italian authors have terminated the flutes of the shafts of their design of Doric columns in the segments of spheres tanged by the surfaces of the fluting. In some few instances the shaft is fluted only at the upper and lower extremities, the other part being left plain, although probably with the intention of being ornamented in a similar manner at some future time. Examples of this are to be found at Eleusis and Thoricus in Attica, at Egesta and Selinus in Sicily, at the temple of Apollo at Delos and at Rhamnus, which last forms a peculiar instance, the columns of the pronaos being fluted the whole length of the shaft in front; with eleven channels, having at the back nine plain surfaces. We have above stated the number of channels to be 16 or 20, but the latter is by far the more usual; examples of which practice are, the Parthenon, Theseum and Propylæa at Athens, with others at Corinth, Delos, Eleusis, Rhamnus, Thoricus, Bassæ, Agrigentum, and in the temple of Ceres, at Pæstum. There are but few examples with only 16 channels, of which number are those at Sunium, and the upper range of the interior columns in the temple of Neptune at Pæstum, in which last mentioned building there are specimens of columns with as many as 24 flutes. The channels were not always circular, but sometimes semi-ellipses, and at others eccentric curves. Doric antæ were never fluted.

The first object which attracts notice in passing the eye up the column, and which breaks the outline of the fluting, is what is termed the hypotrachelium, or under-necking of the capital. This consists of one or more channels cut in recession round the upper part of the shaft; in some instances, as at the temple of Minerva at Sunium, in the Agora at Athens, and in most of the examples at Agrigentum; this division is so fine as almost to escape notice, and in others is very prominent, the channels varying both in size and number. In the Parthenon, and in the Propylæa at Eleusis, and at Rhamnus, there is a single rectangular groove; at the Propylæa at Athens, a groove chamfered on the upper edge, and at the Theseum, a groove chamfered on both edges, so as to form an acute angle at the meeting of the chamfers. At Corinth there are three channels similar to those in the Propylæa at Athens, having a fillet between each two, as also at the temple of Apollo at Bassæ, but in this example the channels are of a curvilinear section. At Pæstum there are three fine channels, which, at their junction with the arrises of the flutes, are cut into the shape of diamonds, the projecting edge of the arris being chamfered off. The hypotrachelium of three channels is considered a mark of antiquity, for although they are not of necessity found in all ancient examples, yet they are never inserted in those of later date. Some writers consider those channels as the commencement of the capital, while others are inclined to think them but a continuation of the shaft. In the other orders the corresponding member is certainly the division between the two parts, all above being giving to the capital, and all below to the shaft; the difficulty in this case arising from the fact of the continuation of the flutes above this point, the space between the hypotrachelium and annulets being precisely similar to the lower portion of the shaft, yet at the same time it is difficult to assign any other reason for the introduction of the grooves, except they serve to mark the division between the two members of the column. Without the intervention

of such a mark as this the capital would have appeared stunted and heavy, but, as it is, the shadow produced by the sinking, marks to the eye a distinct division, and, in appearance at least, increases, at the same time, the length and comparative lightness of the capital.

Above the hypotrachelium, the shaft, with its fluting, is continued for a short distance, and meets the annulets of the capital in a curve or *apothesis;* this portion forming, according to our notion, the necking of the capital. The annulets come next, and form the lower portion of what may be termed the capital-proper, about which there exists no difference of opinion. The following particulars of the number and form of annulets in different examples are furnished by a contributor to "The Builder," to whose valuable writings, on this subject, we shall have occasion to advert more than once in this article:—

"The annulets, in Grecian Doric colums, vary as well in their profile as in their number. Some examples may be interesting, to show the exhaustless genius of the Greeks, even in details the most minute, and that although the general principles of art in the Doric order are the same, yet that they could produce great variety in their details. In the Parthenon, that best and purest of all examples, we find, under the echinus of the capitals in the porticos, five rings, placed on a slope, continued, as it were, from the lower link of the echinus, and in the columns of the pronaos of the same edifice, there are but three rings. In the temple of Theseus, the profile of the annulets is somewhat similar to that of the Parthenon; the rings are four in number, and the under side of the lower arris of each ring is slightly undercut. In the example from the portico at Athens, presumed to belong to the Agora, or market-place, we see how widely the artist departed from the graceful and flowing outline of earlier patterns; this, of the age of Augustus, is one of the latest known examples of Grecian-Doric, yet in many points it cannot be safely recommended for modern imitation. In the temple of Apollo Epicurius, at Bassæ, a building of the pure age of Greek art, the annulets are four in number, resembling in their contour those in the Parthenon, excepting that the second and third rings recede a little from a line drawn from the first to the fourth. At Rhamnus, where are two temples, at Sunium, and in the Dodecastyle portico of Ceres at Eleusis the rings are three in number, profiled like the best examples at Athens; at Egesta and Selinus, they are three in number; at the temple of Jupiter Olympus, at Agrigentum, of Apollo in the isle of Delos, and in the portico of Philip at the same place, at Corinth (where the annulets have a great projection, and are very deeply undercut), in the Hypæthral temple at Pæstum, in the temple of Diana, in the Propylæa at Eleusis, in the Propylæa at Athens (an excellent example) and at Thoricus, the rings are four in number. At the latter place the annulets are remarkable, and probably singular in their way. In the capital from the Pseudodipteral temple at Pæstum, in which many peculiarities are observable; the immense size and projection of the abacus seem to crush the echinus, which has beneath it two rings, under which the flutings curl in the form of leaves. At Selinus, Mr. Woods noticed some remarkable features in the capitals:—'The shape of these capitals is very peculiar; I have seen nothing like them in Greece, except a fragment on a very small scale which I noticed at Corfu. The common Grecian-Doric capitals in the best examples form a sort of ogee, and we find this curve at the third temple, but in the great temple, and in two of the three smaller ones, a deep hollow interrupts the flow of the lines.' These capitals were each cut out of a block of stone thirteen feet square."

The next member of the capital is the echinus, which is similar to an ovolo, or quarter-round moulding, and which, spreading out from above the annulets, serves to support the overhanging abacus. In the best examples it is usually very flat in profile, being little more than a frustum of an inverted cone, having its base rounded off at its edge, and quirked, as it were, where it meets the abacus. Its use seems to have originated from an imitation of the cushion-capitals of the Egyptians, the lower portion only being reserved in Grecian buildings. The diameter of the top of the echinus is equal to, or somewhat greater than, the lower diameter of the column. We refer again to the writer above alluded to.

"In those buildings which belong to the best age of Grecian art—the days of Pericles, and his chief architects, Callicrates and Ictinus—as seen at Athens, Bassæ, Sunium, Thoricus, Eleusis, Rhamnus, and elsewhere, we shall find that the echinus has its lower part either very slightly curved or else perfectly straight; whilst, in buildings of later date, and of equivocal taste, we find that the moulding nearly resembles an elongated or ovate quarter-round, as in the Agora at Athens, and in a building at Cadachio. Professor Donaldson has drawn notice to the general principle which "directed the Greeks in composition of their Doric capitals. From the necking to the abacus, the outline is that of a cyma-reversa, having a projection that varied according to the era, or style of art peculiar to the country; the existing Attic examples being but slightly projecting, while the immense abacus of the orders now remaining at Corinth, Pæstum, and in Sicily, gives a bolder profile to the capital." Some idea may be formed of the vast proportions of the temple of Jupiter, at Agrigentum, when we find that the echinus of each column is formed of two stones, each weighing $21\frac{1}{2}$ tons, held together by plugs or dowels by the centre stone of the abacus, which is in three pieces. In the capitals of the antæ of Greek examples the echinus is generally undercut, so as to form that remarkable moulding called the hawk's-beak, or bird's-beak moulding. The proportionate depth of the abacus and echinus to each other, is not always the same; but, as a general rule, it may be held, that the former member should have the greatest depth. In the Parthenon, the relation, in this respect, is as 11 to 9; at Sunium and at Bassæ, as 7 to 6; at Thoricus, as 6 to 5; at Eleusis, as 12 to 9. In the best examples with which we are acquainted—as, for instance, in the Parthenon and Theseum—the echinus has nearly the same projection as the abacus (it is actually the same in the temple of Apollo Epicurius, at Bassæ); and we shall find, that the sharper is its outline—that is, the more it is remote from the quarter-round—the more it is held in estimation; and that, as it approaches the ovolo in form, so it may be traced to belong to a declining period, or one nearer to the time of the Roman use of the Doric order. If we grant for a moment, that timber construction afforded the first hints for architectural composition, and that the origin of the abacus may be traced to the intervention of a cube of wood between the column and its entablature; where will the advocates of this system find the prototype of the echinus? To the Greeks we must look for adoption of this beautiful moulding, which connects, in such a happy manner, the square abacus with the circular shaft; and truly may it be said to be their own invention, even if we are compelled to admit, that some slight hint for it is to be found among the heavy capitals of Egypt. Professor Hosking has well observed: "Greek architecture is distinguished for nothing more than for the grace and beauty of its mouldings; and it may be remarked of them generally, that they are eccentric, and not regular curves. They must be drawn, for they cannot be described, or struck; so that, though they may be called circular, or elliptical, it is seldom that they are really so; not but that they may be; but if they are, it is consider-

ably the result of chance, not of design. Hence, all attempts to give rules for striking mouldings are worse than useless, for they are injurious; the hand alone, directed by good taste, can adapt them to their purpose, and give them the spirit and feeling which render them effective and pleasing."

The abacus at the top of the capital is of the simplest description, being merely a square slab of stone, of considerable thickness, harmonizing well with the massy appearance of the entire column. It projects considerably beyond the upper part of the shaft, and sometimes even beyond the lower diameter, and always advances in front of the general surface of the epistylium. Where the abacus overhangs beyond the foot of the column, it is considered as an indication of the antiquity of the building; examples of which occur at Corinth, Pæstum, Egesta, and elsewhere. This completes the description of the column.

It may be well to mention in passing, that Doric antæ differ from columns, in maintaining the same width from top to bottom, which equals the average diameter of the column. They have a simple moulding and groove at their base; the capital likewise is very simple, and the abacus and other mouldings are much narrower than in the capital of the column. Antæ are never fluted.

The Doric entablature consists as usual of three members, architrave, frieze, and cornice, the first or lowermost of which, otherwise termed the *epistylium*, is simply a plain fascia surmounted by a broad fillet termed the *tænia*, which forms the separation between it and the frieze, and to which another fillet, with small cylindrical guttæ depending from it, is attached in separate portions beneath each triglyph of the frieze. The epistylium recedes from the face of the abacus, projecting beyond the upper diameter of the shaft, but falling short of the extremity of the lower diameter, so as only partially to overhang the column. A line dropped vertically from the face of the architrave would cut the abacus, pass without the upper portion of the shaft, but fall within it ere it reached the base. The average height of this member, inclusive of the tænia, is equal to the upper diameter of the column.

Above the architrave is the frieze, which forms the most characteristic feature in the whole entablature, although of no greater dimensions than the epistylium. The height of the two members is nearly equal, with but slight variations in any example, the frieze being seldom, if ever, the deeper, more frequently the shallower of the two. The peculiar ornamentation of this portion of the entablature gives it its specific character; being divided into a series of projecting and recessed panels. The distinguishing feature is the *triglyph*, which is a slightly projecting tablet, somewhat wider than the semi-diameter of the base of the column, and channelled vertically with three grooves, or γλυφες, whence the name triglyph. These channels are so disposed, that there shall be a space in the centre of the projecting slab, with a channel on each side of it, and beyond these again, on either side, another equal space, with a half-groove outside, on the edge of the slab, which indeed is nothing more than a chamfered edge. The two channels, and the two halves on the extremities together make up the three grooves, or *glyphs*.

Beneath each triglyph, and attached to a fillet, are a series of guttæ or drops, immediately under the tænia of the architrave. This decoration we have alluded to in describing the epistylium, but although it is attached to that member, it belongs, strictly speaking, to the triglyph, of which it is a continuation; its position, however, in this place, serves a very useful purpose, for it both gives a variety to the otherwise monotonous surface of the architrave, and, at the same time, presents to the eye a sort of connection between this portion of the entablature and the frieze above it. The guttæ are six in number, of a conical form, and are said to represent drops of rain that have trickled down the channels of the triglyph, and settled beneath the tænia; others again suppose them to represent the heads of nails, or screws, used in the wooden structure. The channels of the triglyph are of a triangular section, and are not continued the entire height of the block, although at the bottom they butt against the tænia. Each triglyph is surmounted by a capital, or slightly-projecting band, which, in the Greek examples is of very slight projection, and is not returned at the sides, except in the case of triglyphs at the angles of the building. The position of these ornaments is such, that there shall be one over the centre of each column, and one midway between every pair of columns; but there is an exception to this disposition at the angles of buildings, where the triglyph is not placed over the centre of the column, but is brought up quite to the edge or outer angle of the frieze, so that a line dropped perpendicularly from the outer edge of the corner triglyph, would touch the base of the column. This disposition gives occasion for an alteration of the intercolumniation between the two end columns, these being brought closer together by the space of half a triglyph; an advantage is obtained by this means, inasmuch as an appearance of greater strength is given to the extremities of the colonnade.

The spaces between the triglyphs are called *metopes*, and are usually filled up with sculptures in bas-relief, from which circumstance the frieze was called by the Greeks *zoophorus*, because it contained representations of living figures, men or animals. These metopes are usually of a square form, their breadth being equal to the height of the frieze, but there is a slight variation in different examples. In the Doric portico at Athens, the breadth of the metope is 3′,, 3″ and 3′,, 3″.6, while the height is 3′,, 0″. 7, including the band or capital over it; or without the band, 2′,, 9″. 05; in the temple of Minerva at Athens, the height of the metope, without the band, is 3′,, 11″. 15, and its breadth 4′,, 3″. 35: in the Propylæa, the breadth is 3′,, 8″ .25, and the height 3′,, 9″ . 85, including the band and the bend over it; and in the Theseum, the breadth is 2′,, 6″ .475, and the height 2′,, 5″, without the band. Each metope is surmounted with a band, or capital, similar to that of the triglyph, though not of equal width or projection.

The entablature belonging to the monument of Thrasyllus is an exception to the general rule, the frieze being without the characteristic addition of triglyphs, their place being filled up with wreaths; the guttæ, however, are retained, but instead of being disposed at intervals, they are continued uninterruptedly beneath the fillet.

The Doric cornice consists of few but bold parts, the most characteristic of which are the mutules. These are a series of shallow plates attached to the soffit of the corona, sloping forward, so that the bottom of the mutule in front is considerably lower than at the back, and having their soffits studded with cylindrical or conical guttæ; these guttæ were eighteen in number, and placed in three rows of six each. A mutule was placed over each triglyph, and an intermediate one over each mutule; their width being equal to that of the triglyphs. Under the mutules was generally a plain band, but sometimes an ogee is found in this place. The corona is a boldly-projecting flat moulding, of somewhat greater depth than the abacus of the capital, and is generally finished off above with a small ovolo and fillet supporting the cymatium, which consists of two similar mouldings, but of more imposing dimensions. In raking cornices the mutules are omitted, but a new moulding, termed the *epitithedas*, is added as a finish, which is either an ovolo or cymatium.

When used, the epitithedas was continued a little way at the angles, and terminated against a carved block. The pediment in this order is of a low pitch, and always about the same height, whatever the span may be; upon an average the height equals that of the entablature, more or less, but is scarcely ever so great as to make the tympanum higher than the entablature.

Having completed this general description of the order, it may be as well to say a few words about the proportions observed in the different parts.

The height of the column varies from four times the lower diameter, as in the earliest existing example at Corinth, to $6\frac{1}{2}$ times, as at the portico of Philip, but in the purest examples the height is about $5\frac{1}{2}$ times the lower diameter, the upper diameter being $\frac{1}{6}$ less than the lower. The entablature varies from $1\frac{3}{4}$ to 2 diameters in height, of which $\frac{2}{5}$ go to the epistylium, $\frac{2}{5}$ to the frieze, and the remainder to the cornice.

To afford more detailed information, we give the following proportions from the temple at Sunium, and the accompanying table, as prepared by Mr. Brown.

"The proportions of the temple at Sunium are thus ordered: make the column 6 diameters high, and the entablature $\frac{3}{10}$ of the column, or divide the whole height into 13 parts, of which give 10 to the column, and 3 to the entablature. The upper diameter of the column is $\frac{3}{4}$ of the lower. The capital $\frac{1}{2}$ a diameter, which, being divided into 5 parts, 2 are to be given to the abacus, 2 to the ovolo and annulets, and 1 to the necking. The length of the abacus $1\frac{1}{8}$ diameter. The entablature is to be divided into 8 parts, giving 3 to the architrave, 3 to the frieze, and 2 to the cornice. In dividing the cornice, take $\frac{3}{7}$ for the cymatium, fillet, and moulding, $\frac{3}{7}$ for the corona alone, and leave $\frac{1}{7}$ for that part of the fascia which appears below a horizontal line drawn from the lower front edge of the corona. The whole projection of the cornice is 1 diameter, reckoning from the centre of the column. The capital of the triglyph to be $\frac{1}{9}$ of the whole height of the frieze. The capital or fillet of the architrave to be $\frac{1}{2}$ of the height of the architrave. The architrave to overhang the upper part of the shaft by $\frac{1}{2}$ the difference between that and the lower diameter. In distributing the triglyphs, take $1\frac{1}{4}$ diameter, or 75 minutes for the width of the triglyph and metope, and of this give $\frac{3}{8}$ to the former, and $\frac{5}{8}$ to the latter, or nearly 28 and 47 minutes. Thus a monotriglyph intercolumniation will be $75+75-60=90$ minutes, or $1\frac{1}{2}$ diameter."

A Table of the Proportions of some of the Grecian Doric Orders, according to the Module of Sixty Parts, formed at the bottom of the Shaft of the Column.

	Lower Diameter.	Upper Diameter.	Height of Column.		Architrave.	Frieze.	Cornice.	Intercolumniation.		Pedestal.
	Minutes.	Minutes.	Diam.	Min.	Min.	Min.	Min.	Diam.	Min.	Rise.
Propylæa, or Entrance into the Citadel of Athens	60	—	—		—	—	—	—		—
Portico of the Agora, at Athens	60	47	6	$2\frac{1}{2}$	40	42	21	1	$2\frac{1}{2}$	1 7
Temple of Minerva, or Parthenon at Athens	60	47	5	$33\frac{1}{2}$	43	43	32	1	$17\frac{3}{4}$	1 91 4
Temple at Corinth	60	$44\frac{2}{3}$	4	4	$48\frac{2}{3}$	—	—	1	14	—
Temple of Theseus at Athens	60	$46\frac{2}{3}$	5	$42\frac{1}{3}$	50	$49\frac{1}{2}$	—	1	$37\frac{1}{2}$	1 81 2
Temple of Minerva at Sunium	60	$45\frac{3}{4}$	5	54	$48\frac{1}{2}$	$48\frac{1}{2}$	—	1	28	—
Temple of Jupiter Nemeus, near Argos	60	49	6	31	$38\frac{2}{3}$	$43\frac{1}{2}$	—	—		—
Temple of Jupiter Panhellenius at Argive	60	$44\frac{1}{2}$	5	24	$51\frac{1}{3}$	$51\frac{1}{2}$	—	1	41	—
Portico of Philip, King of Macedon, at Delos	60	$49\frac{1}{2}$	6	$32\frac{1}{2}$	$38\frac{1}{2}$	$43\frac{3}{4}$	$25\frac{1}{2}$	2	$42\frac{2}{3}$	—
Temple of Apollo at Delos (plain shaft)	60	$42\frac{1}{2}$	6	$3\frac{3}{4}$	$49\frac{2}{3}$	$42\frac{1}{2}$	—	—		—
Temple of Minerva at Syracuse	60	46	4	$24\frac{1}{2}$	$44\frac{1}{2}$	40	—	1	$5\frac{2}{3}$	—
Temple of Juno Lucina at Agrigentum	60	$45\frac{1}{3}$	4	42	55	45	—	1	15	—
Temple of Concord at Agrigentum	60	46	4	$48\frac{1}{4}$	$46\frac{4}{5}$	$46\frac{1}{3}$	25	1	$10\frac{2}{3}$	—
Temple of Selinus	60	46	4	$21\frac{3}{4}$	$46\frac{1}{3}$	$44\frac{2}{3}$	—	1	$2\frac{1}{3}$	—
Temple of Jupiter Selinus	60	$35\frac{1}{2}$	4	$34\frac{1}{2}$	52	$44\frac{2}{3}$	26	—		
Pseudo-dipteral Temple at Pæstum	60	$40\frac{1}{3}$	4	27	50	—	—	$59\frac{1}{2}$	$67\frac{2}{3}$	—
Hexastyle Temple at Pæstum	60	43	4	$47\frac{3}{4}$	$45\frac{3}{4}$	$44\frac{3}{4}$	$24\frac{3}{4}$	1	$1\frac{1}{3}$	—
Hypæthral Temple of Neptune at Pæstum	60	$41\frac{1}{4}$	4	8	$42\frac{1}{3}$	$40\frac{1}{2}$	$21\frac{1}{2}$	1	$4\frac{3}{4}$	—
Inner Peristyle of Temple of Neptune	60	43	1	$13\frac{1}{3}$	39	—	—	1	$22\frac{1}{4}$	—
Upper Columns to ditto	60	$44\frac{1}{3}$	3	50	68	—	—	2	49	—
Temple of Egesta (plain shaft)	60	$44\frac{3}{4}$	—		$49\frac{3}{4}$	$52\frac{2}{3}$	$40\frac{3}{4}$	1	11	—

In comparing the above with the table on the next page, in which the dates are given, it will be readily observable with what regularity the proportionate height of the columns increased from the earliest example at Corinth to the latest, the Agora at Athens: the last, however, forming somewhat of an exception to the rule, the height being less in this case than in the two previous examples, viz; those of the temple of Jupiter Nemæus, and of the Portico of Philip of Macedon. The diminution of the shaft will be seen to average about 15 minutes, the upper diameter ranging from $49\frac{1}{2}$ in the portico of Philip, a late example, to $35\frac{1}{2}$ in the temple at Selinus, one of the earlier buildings; thus affording additional proof of the comparative lightness of the later structures. We have to call attention likewise to the general equality in height between the architrave and frieze, noticing at the same time one or two exceptions in which there is a considerable variation, especially in that at Agrigentum; the height of the architrave of the upper colonnade in the temple of Neptune is remarkable, as is also that of the frieze and cornice at Egesta.

The following useful, though somewhat different table, is the compilation of the writer to whom we have previously alluded.

This table exhibits at one view the proportions of the columns in some of the principal buildings in Greece and its colonies, concluding with the scale which the Roman and Italian schools assigned to the Doric.

Date of Erection.	Name of Building.	Name of Architect.	Height of Column.		Diameter.		Number of Diameters high.	Number of Columns in Portico.	Number of Columns on the side
			ft.	in.	ft.	in.			
About 800 B. C.	Temple at Corinth		23	8	3	10	$4\frac{2}{35}$	6	—
600 or 700 B. C.	Great Hypæthral Temple at Pæstum		28	10	7	0	$1\frac{1}{21}$	6	14
500 B. C.	Temple at Selinus		32	6	7	6	$4\frac{1}{3}$	6	12
	Octostyle at Selinus		48	7	10	7	$4\frac{3}{5}$	8	16
	Temple of Minerva at Syracuse	Probably Archias of Corinth.	28	8	6	6	$4\frac{16}{39}$	—	—
About 450 B. C.	Temple of Hercules at Agrigentum		33	0	7	0	$4\frac{5}{7}$	6	14
	Temple of Concord at ditto		22	2	4	8	$4\frac{3}{4}$	6	—
500 B. C.	Temple of Jupiter Panhellenius at Egina	Libon.	17	1	3	2	$5\frac{9}{19}$	6	—
About 461 B. C.	Temple of Theseus		18	7	3	3	$5\frac{28}{39}$	6	13
448 B. C.	Parthenon	Ictinus.	34	0	6	2	$5\frac{14}{37}$	8	17
About 430 B. C.	Temple of Apollo at Bassæ	Ictinus.	19	6	3	7	$5\frac{19}{43}$	6	15
	Temple of Minerva at Sunium	Ictinus.	19	7	3	4	$5\frac{7}{8}$	6	—
Age of Pericles.	Temple of Ceres at Eleusis	Corabus.	—		6	6	Supposed $5\frac{1}{2}$	12	—
Age of Pericles.	Temple of Diana Propylæa at Eleusis		14	10	2	7	$5\frac{3}{4}$	2 in antis.	—
	Temple at Rhamnus	Alcamenes, a pupil of Phidias.	13	4	2	4	$5\frac{1}{2}$	6	12
	Temple of Apollo, Delos		18	8	2	11	$6\frac{2}{5}$	—	—
About 338 B. C.	Portico of Philip of Macedon, Delos		18	8	2	10	$6\frac{2}{5}$	—	—
	Temple of Jupiter Nemæus		33	8	5	2	$6\frac{16}{31}$	6	—
100 B. C.	Agora, at Athens		26	2	4	4	$6\frac{1}{25}$	4	—
Time of Augustus.	Theatre of Marcellus, at Rome		21	0	3	0	7	—	—
About 80 A. D.	Coliseum		27	3	2	10	$9\frac{21}{34}$	—	—
About 300 A. D.	Baths of Diocletian		—		—		8	—	—

The intercolumniation of this order differs from that of all the others, inasmuch as the intercolumns are determined not by the diameters of the column, but by the arrangement of the triglyphs; and the different methods, instead of being distinguished as *pycnostyle, eustyle, aræostyle, &c.*, are comprehended under the terms *monotriglyph, ditriglyph, &c.*, according to the number of triglyphs over each intercolumn; the former term designating the arrangement in which there is but one triglyph between the columns, the latter that in which there are two within the same limits. This method of disposing the columns naturally arises from the employment of the triglyph, for this ornament forms so conspicuous an object in the elevation, that it was necessary to make its position conform with the other principal members of the order, of which the column is the most important, so that the colonnade and entablature might present to the eye a similar arrangement. Had the triglyphs been placed in the frieze without reference to the position of the columns, the eye, after passing up the length of the column, would have been confused upon reaching the frieze, and probably would have stopped short at that member, there being nothing to carry it upward to the cornice. Did we adopt the Vitruvian theory, the position of the triglyph would readily be accounted for in another way, for it stands to reason, that the feet of the rafters would be placed immediately over their support.

It being necessary then that the triglyph should stand over the centre of each column, and the proportion of the metope or space between the triglyph being determined, we only require the height of the frieze, and the intercolumniation is fixed. The width of the metope being about equal to the height of the frieze, and the triglyphs somewhat less, it is evident, that to place a column under every triglyph, would be impracticable, without increasing the height of the frieze quite beyond proportion; there would be scarcely room for the feet of the columns, much less for any space between. It became necessary therefore to place another triglyph in the centre of each intercolumn, with two metopes instead of one: this arrangement answered very well, and is the most frequent in Doric temples, and indeed is seldom departed from in any buildings. By inserting another triglyph, you are compelled to add another metope, and this makes the intercolumn half as wide again, which is almost too wide to suit the requirements of taste, as well as the proportions and construction of Doric buildings. There are very few instances of this arrangement, and these only in the centre intercolumn opposite the entrances, where greater space was required; this is especially noticeable in the Propylæa, where a large space was required for the admission of chariots. It may be supposed, that the monotriglyphic method would cause the columns to appear too closely set, and this certainly would be the case in some instances, where the columns are less than a diameter and half apart, were it not

that the shafts converge so rapidly towards the upper diameter as to leave a space under the soffit of the architrave, even in such instances equal to more than twice the upper diameter.

The peculiar position of the extreme triglyph has already been noticed in speaking of that member, as also the effect produced by it in lessening the extreme intercolumn by the space of half a triglyph; but there still remains to notice another peculiarity, which was first published by Mr. Donaldson; we allude to the inward inclination of the outer columns.

"The axis of the columns of the Parthenon," says he, "both on the flanks and on the fronts, as well as those of the temple at Egina, and of Concord at Agrigentum, have a considerable inclination inwards (a circumstance I am not aware to have been before noticed) though not to such a degree as required by Vitruvius, and not confined, as he directs, to the columns of the peristyles only." Vitruvius thus directed:—"The bases being thus completed, we are to raise the columns on them. Those of the pronaos and posticum are to be kept with axes perpendicular: the angular ones excepted, which, as well as those on the flanks right and left, are to be so placed, that their interior faces towards the cella be perpendicular. The exterior faces will diminish upwards, as above mentioned. Thus the diminution will give a pleasing effect to the temple."

Mr. Bartholomew alludes to the same circumstance thus:—

"The ancients, knowing how much more secure were their fabrics when made to settle together and consolidate by their own gravity, set the lateral columns of their temples with their axes falling towards the cells, so that the inner faces of the shafts of the columns should be perpendicular, and the outer faces of them receding the whole quantity of columnar diminution, in order to afford to the building a more solid, pyramidal, and graceful appearance; and by this shrewd device they rendered the avenues between the side-walls and the colonnades of their temples no wider next the soffits of the architraves than down upon the pavement; and it is not improbable, that the preservation of this symmetry led to the omission of the inner columns of the ancient Pseudodipteral temples; whereas the moderns, in general, not attending to his dynamic and optical nicety in architecture, so set their columns, that when we walk down a modern collonnade, we cannot divest ourselves of the idea that the axes of all the columns are falling outwards: and, indeed, accurate admeasurement would often find this to be no illusion, since the work, not erected so as to fall together, will, in general, with the slightest inevitable settlement, expand at its upper part." It is worthy of remark, that, in many instances, the angular columns are made somewhat thicker than the others, so as to give them an appearance of much greater strength.

Having arrived thus far, we cannot do better than give descriptions of some of the more noted edifices belonging to this order, amongst which are the Parthenon, Theseum, the ancient temple at Corinth, the Propylæa at Athens, and the Poseidonium at Pæstum. The following accounts are selected from Mr. Godwin's lectures on Architectural Antiquities."

"The Parthenon, or the temple dedicated to the virgin-goddess Minerva (the Greek word *παρθένος*, signifying a virgin), was designed by Ictinus and Callicrates, about the year 438 B.C., whilst Phidias wrought the marble figures into life by his magic touch. This temple, erected upon the site of the old Hecatompedon destroyed by the Persians, is justly looked upon as the finest example of the Grecian Doric, and has excited for 22 centuries the admiration and delight of all who have seen it. With the words of the noble author before quoted, all will probably agree. 'In the majestic simplicity of its general design, the grandeur of its proportions and the exquisite taste and skill displayed in the execution of its ornamental parts, it is undoubtedly the most perfect, as well as deservedly the most celebrated, production of Grecian art.' (Lord Aberdeen's Inquiry, p. 142.)

"When Sir George Wheeler and Dr. Spon visited this edifice, A.D. 1676, the temple was entire. In the year 1687 Athens was besieged by the Venetians, when a shell falling on the structure, the Parthenon was reduced to the state in which it was seen by Stuart and Revett. This celebrated temple had at each end a portico of 8 columns in front, and on the sides were 30 more, making 46 to the colonnade which surrounded the cell of the building. The breadth of the front of the building is 101 feet, the length 227 feet on the upper step, and the height 65 feet. The columns are 6 feet 1 inch in diameter, those at the angles are 2 inches more, and the distance from column to column is 7 feet 11 inches. The sculptures of the Parthenon extended to a range of 1,100 feet, consisting of upwards of 600 figures. Behind the great porticos, there are two of smaller dimensions, which are called the pronaos and posticus; these inner porticos have in each 6 columns. The portion of the building enclosed by the columns was divided by a cross wall into two parts, whereof the larger, called the cella or naos (ship) answered to our nave; the smaller part, in which was the public treasury, was called the opisthodomus. In this part, according to Wheeler, were six columns, but no vestige remains of them. The cell, where was placed the famous statue of Minerva by Phidias, was open to the sky in the centre (whence such a temple was called hypæthral from the Greek *ὑπὸ*, under, and *αἰθὴρ*, *æther*, air), having a colonnade round it, supporting a gallery above, in which was a second row of columns. These have all likewise disappeared, but the circles were traced by Stuart on the pavement whereon the lower range of columns had stood. The sculptures in the pediment of the eastern front represented the introduction of Minerva among the assembled gods, giving us an admirable idea of the mythology of the ancients, each of the deities being distinguished by his or her peculiar symbols. The metopes or spaces between the triglyphs, recorded the battles between the Centaurs and the Lapitha, a fruitful subject of illustration among poets as well as sculptors, and a favourite theme with the Greeks, from their famous heroes Hercules and Theseus bearing a prominent part in the contest; fifteen of these metopes are in the British Museum. The western pediment contained a representation of the contest between Minerva and Neptune (in the opinions of Colonel Leake and Mr. Cockerell, this contest was in the eastern pediment); but the most celebrated sculpture is that which represents the Panathenaic procession: this composition is 3 feet 4 inches high, and was continued in the frieze quite round on the outside wall of the cell of the temple. The figures of these groups, which occupy a length of 520 feet, are generally allowed to be of finer execution than those in the metopes.

"'With respect to the beauty of the basso-relievos,' says the great Flaxman, 'they are as perfect nature as it is possible to put into the compass of the marble in which they are executed, and that of the most elegant kind.' Another sculptor, Rossi, calls them 'jewels.'

"The Panathenaic procession, which, with fifteen of the metopes, formerly likewise belonging to the Parthenon, now adorns the British Museum, under the name of the Elgin Marbles, consists, as before observed, of many hundred

figures. Among them are several equestrian figures, which are designed in the most admirable manner, and are remarkable for the varied attitudes of the horses, and for the ease and grace of the riders. Other figures in the procession are charioteers in their cars, one of whom is supposed to be the victor in a chariot-race, as a man is about to crown him. Then follow men carrying trays; then the sacrificers and the oxen, each Athenian colony sending an ox to this great festival. Females are also present; some carrying dishes or pateras, others bearing pitchers of water. Two of the young females had situations of great importance, their office being to carry the sacred baskets. Several gods and goddesses are likewise introduced: they are seated to denote their dignity. These figures are all in high relief, so that they are visible at some distance; and although it is impossible now to decide how much was the actual work of Phidias himself, it is highly probable that they, as well as the other sculptured decorations of the temple, were all designed by the great master. (It is known, he practised the art of painting previously to that of sculpture.) It has been ascertained, that they are as carefully finished behind as before, and in places which could not be visible when once they had reached their destination; hence, it is justly inferred, that all these sculptures had to undergo the ordeal of a searching criticism of the public eye, before they left the artist's studio.

"In addition to the embellishments already described, which adorned the temple, Phidias made the celebrated statue of Minerva which stood in the cell, or open part of the building. This figure, formed of ivory and gold, was thirty-seven feet high. Pausanias says that it stood erect; the goddess was represented with her garments reaching to her feet, helmeted, and with a Medusa's head on her breast; in one hand she held a spear, and on the other stood a Victory of about four cubits high. Monsieur Quartreinere de Quincy, who bestowed great pains in investigating the subject of ancient sculpture, has calculated, that the value of the gold employed on this famous statue was equal to £130,000 sterling.

"A fac-simile of the Parthenon, as far as the architecture is concerned, has been erected at Edinburgh, on the Calton-hill, in a situation resembling the Athenian Acropolis. Mr. Bankes proposed it as the model for the Fitzwilliam Museum, at Cambridge. The proportions of its Doric order are imitated in the portico of Covent Garden Theatre.

"The Temple of Theseus which is generally reckoned to belong to the age of Pericles, and earlier in date than the Parthenon, is one of the noblest monuments of Athenian magnificence, and, in the the time of Stuart, was one of the most perfect. 'The sanctuary of Theseus was raised by the Athenians after the Medes were at Marathon, when Cimon, the son of Miltiades, expelled the people of Scyros, a retribution for the death of Theseus, and carried his bones to Athens.' (Pausanias.)

"Plutarch places this event at a date which is generally considered equivalent to the year 467 B.C. The Parthenon is, by some writers, believed to have been commenced about 448 B.C. (the year in which Cimon died), and to have occupied sixteen years in erection. In the opinion of Lord Aberdeen, 'The temple of Theseus may be considered as nearly coeval with the buildings of the Acropolis, or perhaps of an origin somewhat earlier.' (Inquiry, p. 143.) The Theseum is built of Pentelic marble, and is raised upon two steps, being peculiar in this respect. The portico at each end consists of six columns in front; at each side are eleven columns, not counting the angle-columns of the portico; so that the building is surrounded by thirty-four columns. Behind the porticos are others, consisting of only two columns between antæ; there are three deep recesses, which lead to the cell. There is here no division in the internal part, where it is presumed that the remains of Theseus were buried. This temple is 104 feet long, 45 feet wide, both dimensions being taken on the upper step, and 25 feet 2 inches high; the diameter of the columns is 3 feet 3 inches. The sculptures in the metopes were representations of the exploits of Theseus, and of the labours of Hercules, who appears to have been honoured in this temple, as well as Theseus, his kinsman and friend. The frieze of the wall behind the eastern portico was adorned with a representation of a battle and victory, in which six of the divinities are present; three of whom are Jupiter, Juno, and Minerva. Among the combatants is one of superior stature and dignity, hurling at his assailants a stone of prodigious size; he is supposed to be Theseus, in the act of overthrowing the Persians at Marathon. The battle between the Centaurs and Lapithæ was sculptured on the wall behind the western portico. The sculptures (of which are casts in the British Museum) are, according to Pausanias, supposed to be the work of the famous Michon.

"It has been discovered of late years, that the Parthenon, and nearly all the buildings at Athens, had colours applied to their different enrichments; but it does not appear that the advocates of Greek polychromy have clearly made out that this practice belongs to the pure age of Pericles and Phidias. It is much more likely to have been introduced long after their time.

"The temple of Corinth is probably the most ancient specimen of the Doric order in existence. It is built of a rough porous stone, and is supposed to have had porticos of six columns, five of which remain in the western front, and six are seen on one flank; its arrangement, perhaps, was similar to that of the temple of Theseus; the columns are 5 feet 10 inches in diameter, and their shafts, 21 feet in height, are composed each of a single stone. There is no sculpture upon the temple, as all above the architrave has long since disappeared. Since Stuart's time, five of the columns which appear in the flank, in his work, have been blown into fragments by gunpowder, to assist in building the house of a governor of Corinth. Lord Aberdeen observes, 'It has been said, that this temple was dedicated to Venus; but, in fact, no information is to be obtained respecting its origin. Whatever may have been its destination, no one can doubt, from the appearance of the ruins alone, that they formed part of a structure of the most remote antiquity.

"One of the noblest efforts of the genius of Ictinus is to be seen in the temple of Apollo Epicurius, in Arcadia. It offers many architectural peculiarities, and exhibits a greater variety of details than are usually met with in the Grecian temples.

"Pausanias, speaking of this building, which is at Bassæ, near Phigalia, states, that 'the temple of Apollo Epicurius (the deliverer), which, together with the roof, is of stone, surpasses all the temples which are in Peloponnesus (with the exception of that in Tegea) in the beauty of the stone, and harmony of the proportions.'

"The entrance to the temple was facing the north, contrary to the usual practice. The temple was 47 feet broad, 125 feet long, and ascended by three steps. There were six columns in each front, and fifteen on each flank, all 3 feet 7 inches in diameter, and 19 feet 6 inches high. In the interior of the cell were *attached* columns, of the Ionic order, of a very ancient character, (together with a single insulated column of the Corinthian order,) over which, on the four sides of the cell, ranged the sculptured frieze. The columns and walls are constructed of the hard and beautiful limestone of the country, but the sculpture and roof are of marble. It would

not appear, from Mr. Donaldson's description, that any decorations existed in the pediments, or metopes. 'The arrangement of the engaged columns of the cella is very peculiar. A similar disposition has never hitherto been found, though, perhaps, in the temple of Apollo Didymæus, at Branchidæ, near Miletus, the projecting pilasters conveyed the same effect, less distinctly expressed. The spaces between the Ionic columns seem to afford admirable situations for statues, as they would be secured by the columns on each side, and by the soffits above, from the occasional inclemencies of even that mild atmosphere.'

"The Propylæa, a Doric structure, forms the only entrance to the Acropolis of Athens. Pausanias says, 'There is only one entrance to the Acropolis, it being in every remaining part of its circuit a precipice, fortified with strong walls. The entrance was fronted by a magnificent building, called the Propylæa, covered with roofs of white marble, which surpassed, for beauty, all that he had before seen. This was begun during the ministration of Pericles, B.C. 437, and was finished in five years (Mnesicles being the architect), at an expense equivalent to £464,000. The front of the Propylæa consisted of six columns, and at the back of the building was a small portico; between the two was the wall, in which were five gates. The centre reached from the platform to the height of the entablature; it was 13 feet wide, and was used on solemn occasions for the chariots. The road-way was between two rows of Ionic columns; a gate of 6 feet wide, and of less height than the centre, occupied each side, and beyond them were two smaller doorways, which were used for ordinary passage. On the right of the Propylæa was a building called the temple of Victory-without-wings. On the left, was an edifice adorned with paintings, the work of Polygnotus; the subjects chiefly from Homer; and it is supposed, that herein stood a group of the Graces, draped, the performance of the celebrated Socrates, who pursued his father's profession of a sculptor, until he devoted the energies of his wonderful mind to the study of philosophy.

"Similar in plan to the building at Athens, is the Propylæa at Eleusis, and, in design, little inferior to its Athenian prototype. It was erected, together with the Temple of Ceres, to which it served as a vestibule, and the connected Temple of Diana-Propylæa, by Pericles, for the solemnization of the Mysteries of Ceres, the most sacred among the religious rites of Greece.

"The Propylæa bears a striking resemblance to that at Athens, having at each end a portico of six columns, five gates, and two rows of Ionic columns within. To make the central opening large enough to admit chariots, the usual arrangement is departed from, by the addition of a triglyph in the frieze over the space between the central columns. The pavement, the steps, and every part of the superstructure, were of fine Pentelic marble; the roof, also, was covered with marble slabs, worked into the shape of tiles; the joints of these tiles were covered with others, which follow the slope of the roof, to prevent the admission of water. This ingenious contrivance was the invention of Byzes, of Naxos; and it was so highly appreciated by the Greeks, that they honoured the inventor with a statue. The termination of the joint-tiles was formed by an upright tile, on which was painted the lotus. Byzes lived 580 years before the Christian era.

"After passing through the Propylæa at Eleusis, the votaries had to enter another building, forming a second vestibule to the grand mystic temple. The order in this building was the Ionic. Beyond this vestibule was the Temple of Ceres, which was protected by the sacred inclosure, or wall. In front was a portico of twelve columns, which have the peculiarity of not being fluted from top to bottom, as Doric columns usually are, but their shafts plain throughout their whole height, with the exception of a part at their top and at the bottom of each, about 7 inches high, which is fluted. Within the temple, according to a passage in Plutarch, it is imagined there were two ranges of columns, with others over them. The architect of this building was Xenocles.

"In front of the Eleusinian Propylæa was the temple of Diana Propylæa, presenting an arrangement in its porticos differing from any examples we have hitherto noticed; instead of columns at its angles, antæ, which are often improperly called pilasters, terminate its fronts: the distinction between the Greek antæ and Roman pilasters is very great. The former were never diminished (or so slightly as not to appear so to the eye), and were not fluted, their capitals consisted of straight lines; whereas the Roman pilasters were diminished like their columns, frequently fluted, and their capitals generally resembled those of the accompanying columns. The temple of which we are speaking, was small, with a front measuring only 20 feet 10 inches on its upper step; its length 39 feet 9 inches, and its height to the top of the cornice 20 feet 6 inches; the building was of Pentelic marble, but with roof-tiles of baked clay.

"At Olympia, in the Peloponnesus, once existed a magnificent hexastyle temple of Jupiter, of which the dimensions are presumed to have been 230 feet by 95 feet. Mr. Dodwell measured a column, of which the diameter was 7 feet 3 inches. Within this building was enshrined the master-piece of Phidias, his statue of Jupiter, of gold and ivory, 50 cubits high.

"At Rhamnus in Attica, on the sea-coast, is a fine Doric temple of Nemesis, which stands in a noble situation, elevated 300 feet above the sea. Pausanias says that it was built by Alcemenes, the pupil of Phidias. This temple, and a smaller one adjoining it, dedicated to Themis, were inclosed by a wall of white marble, remains of which are yet to be traced. The temple of Nemesis had at each end porticos of 6 columns, and flanks containing 12 each; the external columns, like those to the temple of Ceres, were only fluted at top and bottom. It is ascertained that the mouldings of the cornices were painted red, a practice adopted by the Greeks in other temples. The details in this building are very fine. Close to it is the small building which bears the name of Themis, but which is supposed to be the original temple of Nemesis, injured by the Persians; and the Greeks not caring to repair a structure desecrated by their enemies, chose rather to erect another. The smaller building is in fact of an earlier style, being one of the class called *in antis*, a mode of building well known to be of great antiquity. It is very similar to the small temple of Diana at Eleusis.

"At Sunium, which is a promontory forming a southernmost point of Attica, are the remains of two Doric buildings; one is a Propylæa, the porticos of which have two columns placed between antæ. The other building is a temple dedicated to Minerva-Sunias. The portico consisted of 6 columns, and 10 have been ascertained on the flanks; but the building is so much in ruins, that the exact number cannot be clearly made out. The structures are of marble, highly finished, and belong to the best ages of Grecian architecture. 'The striking remains of the temple of Minerva on the promontory of Sunium are, in all probability, to be attributed to the same authors.'

"At Thoricus, about eight miles to the north of Cape Sunium, are the remains of a singular Doric building, which was found half-buried in the sand, which being cleared, a portico was discovered, having 14 columns on each front, and 7 in each return; and as no remains of walls were

discovered within the area, it is conjectured that the building was not a temple, but an open portico, perhaps an agora; these columns are only fluted at their upper and lower extremities.

"Leaving Attica, we shall now pass into Sicily, where we find the remains of one of the most astonishing specimens of Doric architecture, surpassing in magnitude all that we have hither to noticed. This is the celebrated temple of Jupiter Olympius at Agrigentum, now called Girgenti, and which Virgil styled, from a neighbouring river, Agragas. It was the wealthiest and most powerful city of Sicily, and according to Diogenes Laertius, contained within its territory 800,000 persons. 'The temples of Agrigentum, numerous and costly as they are, appear to have arisen during little more than a single century. The prosperity and independence of the city commenced with Theron, about 450 years before Christ; after the battle of Himera (fought on the same day as that of Salamis), his thoughts were entirely turned to its decorations, and the Carthaginian prisoners were made to assist by their labour in the erection of trophies to perpetuate the glory of their conquerors. The Agrigentines continued in this employment until a second and more successful invasion of the Carthaginians found them occupied in completing the temple of Jupiter Olympius, the greatest in the island, and one of the most stupendous monuments of ancient times.'

"The temple of Jupiter was, in its proportions, truly colossal, and it ranked among ancient Greek temples as second only to that of Diana at Ephesus, (which was 425 feet long, and 220 feet in breadth); it was 369 feet in length, its breadth 182 feet, and its height 120 feet, in which dimensions Mr. Cockerell is of opinion that it exceeded the building at Ephesus. Unlike other Doric structures, in this temple the columns are not detached from the walls, thus they present only the appearance of half-columns; these, however, are 13 feet in diameter, so that if the columns had been disengaged, their circumference would have been more than 40 feet, a dimension exceeding the largest columns in Egyptian architecture. (The Roman-Doric column, erected by Sir Christopher Wren, called the Monument, is only 15 feet in diameter, though of a proportion much loftier). The echinus of the capitals is formed of two large stones, each weighing 21½ tons; the triglyphs are in single stones, each weighing 12¼ tons; few of the stones employed in the entablature weigh less than 8 tons; and a man could stand in one of the flutings of the columns. As compared with a modern building, we may observe, that the width of the cell is two feet more than the nave of St. Paul's, and the height exceeds it by 18 feet. The front portico, in which were 7 columns, had the battle between the Gods and the Titans represented in the pediment; and in that of the other portico was sculptured a representation of the siege of Troy, in which each hero was distinguished by the peculiarity of his dress and arms. (Diodorus). In the interior was a double row of pilasters ranging like the pillars of a cathedral; the attic story above the pilasters was supported by the figures of the rebellious and defeated giants, most appropriately placed there to contribute to the glory of Olympian Jove, whose power they dared to oppose. The proportions of the Titans are as vast as the other parts of the structure: being 25 feet in height; with heads alone 3 feet 10 inches, and chests 3 feet across.

"The other temples of Agrigentum were very numerous; in the year 1790, by Sir Richard Colt Hoare, 11 could be traced in different stages of dilapidation. The next in size to that of Jupiter was one dedicated to Hercules, which was 154 feet long, and 55 feet broad, having 6 Doric fluted columns in each front, and 14 on each flank; the columns were 7 feet in diameter at bottom, and only 4 feet 10 inches below the capitals, showing a very great diminution.

"At Selinus, or Selinuntium, (so called from the great quantity of parsley, σελινον), on the southern coast of Sicily, were six magnificent Doric temples, probably the largest ever erected in this style, and which appear to have been overthrown by an earthquake. One of these is believed to have been 331 feet long, and 161 feet broad, with columns 60 feet high; a stone, which is supposed to have formed part of an architrave, is 40 feet long, 7 feet deep, and 3 feet thick, and some of the columns were found to be 12 feet in diameter, and others 10 feet 10 inches, and 48 feet high. Near these ruins were the remains of a hexastyle peripteral temple, computed to have been 186 feet long, and 76 feet broad on its upper step, and to have had 36 columns in all, 6 feet 8 inches in diameter. Another temple, not far from these, was 232 feet by 83 feet on its upper step, with fluted columns, 6 in each front, and 16 on the flanks. The other three temples are supposed to have been unfinished when they were thrown down. One of these had porticos of 7 columns in front with 17 on each flank; another had 6 columns in the porticos, and 16 on each flank. In the quarry near Campo Bello, whence it is presumed the materials were derived, are yet some shafts of columns, 10 feet in diameter, and one of 12 feet, still joined to their natural bed of stone. Mr. Wood measured one block of an architrave, 26 feet 2 inches long, 4 feet 9 inches wide, and 6 feet 10 inches high. The city was, 409 B. C., nearly destroyed by the Carthaginians.

"At Segeste, the ancient Ægesta, is a famous Grecian-Doric temple, almost entire, standing in a splendid situation on the brow of a precipice. There are 6 columns in each front, and 14 at each side, making 36 in all; these are about 30 feet high; the length of the building is 190 feet, its width 78 feet; the stones composing the architrave are of great size, and one extends over two columns: the date of it erection, as well as the nature of its dedication, are unknown. The columns, which are fluted, are 6 feet 7 inches in diameter at the base, and 4 feet 11 inches below the capital.

"In a notice of Grecian-Doric architecture, we must not omit to speak of some ancient temples in Italy, namely, at Pæstum, the ancient Posidonium, so denominated from its tutelary God, Neptune, who, by the Greeks, was called Ποσειδων. From its unhealthiness, the place had, in very early times, fallen into decay, and Augustus visited the temples as venerable antiquities in his day; but they were completely forgotten, until in 1755 discovered by an artist of Naples. Among the ruins, which are very extensive, are three buildings of imposing character, two of them are temples. The temple of Neptune, raised on 3 steps, was 194 feet long, and 78 feet broad, having 6 fluted columns in each front, and 14 (including the angular ones) at each side. The entablature and capitals were equal to half the height of the columns, of which the shafts only were 27 feet, the lower diameters 6 feet 10 inches, the upper diameter 4 feet 8 inches, and with 24 flutings; the intercolumns are 7 feet 7 inches wide. The cell is 90 feet by 43 feet, having 14 columns in 2 rows, with shafts 16 feet 11 inches high, 4 feet 9 inches in diameter, and with 20 flutings. These columns support a deep architrave, on which rises another set of columns, about 11 feet high. The largest stone in this building is 13 feet 8 inches by 4 feet 8 inches by 2 feet 3 inches. Professor Wilkins, in this temple, detects a close resemblance to the temple of Solomon, (Prolusiones). The temple of Ceres is in a lighter style than the former building. It is 108 feet

long, and 48 feet broad, with the same number of columns, as in the temple of Neptune; the diameter of the columns is at bottom 4 feet 3 inches; at top, 3 feet 3 inches; and their shafts have 20 flutings. The third building is called a Basilica, because there is no appearance of a cell, or altar. It is 170 feet long, and 80 broad; and it is raised on three steps, having nine columns in each front (the only example of such arrangement), and eighteen on each side, with the lower diameter 4 feet 6 inches, and 20 flutings. Both fronts have a vestibule, and the interior was divided by columns. The date of these structures is unknown. One of the most ancient Doric temples in Greece is in the island of Egina; this was a hexastyle temple, dedicated to Jupiter Panhellenius. "It is said by Pausanias to have been built by Eacus, considerably before the Trojan war, a story wholly incredible, but which serves to prove that it had outlived all tradition of its real origin. It is still nearly entire." There were twelve columns on each flank, making thirty-six in all, of a porous stone, covered with a thin stucco, and the architrave and cornice were painted in colours. Fifteen statues, formerly belonging to this temple, are now at Munich: they are supposed to represent the Greeks and Trojans contending for the body of Patroclus; they have been restored by Thorwaldsen. Illustrations of the Temple of Jupiter have been published by Mr. C. R. Cockerell, and have proved a valuable addition to our knowledge of Doric architecture.

Modern examples of this order are to be seen in Covent Garden Theatre; the Corn Market, Mark Lane, where the details of the monument of Thrasyllus are copied; in the new galleries and entrance of the British Museum, where polychrome is introduced; and at the entrance-gateway to the Terminus of the North Western Railway.

The origin of the Doric order has ever been a disputed point amongst writers upon the subject, some following one theory, and some another. Vitruvius, whose opinion is valuable, as coming from the oldest writer upon architectural matters, will have it, that the earliest stone temples of Greece were but imitations of the wooden structures previously employed, and that the members of the Doric order, both structural and ornamental, owe their origin to similar parts in the less permanent building. This primitive mode of building is supposed to have been similar, in some respects, to the log-houses erected by colonists of the present day, consisting of trunks of trees fixed vertically in the ground, at short distances from each other, and forming the support to the several members of the roof. From the various portions of this timber construction, are supposed to have been derived those of the later stone edifice. The following opinion as to some of the corresponding parts of the two kinds of structures, is given by Vitruvius:

"In the upper part of all edifices, timbers, called by various names, are disposed, which, as in names so in uses, differ. The trabes are those laid over the columns, parastatæ and antæ, in the contiguations and floors. If the span of the roof is great, under the culmen, in the top of the fastigium, are disposed columens (from whence columns derive their name), transtræ, and capreols; but if the span is small, columens and canthers, projecting to the extremities of the eaves. Above the canthers are the templats, and over them, out under the tiles, are the assers, projecting so far as to shelter the walls. Thus each, according to its use, has its proper place and order. This disposition of the work, the artificers, when they erected sacred edifices, imitated in sculptures of stone and marble; and this invention the ancient workmen thought proper to pursue. Thus, whenever they constructed any building, they laid the joists from the interior walls to the extreme parts, then built up the interjoist, and, to give the work a pleasing appearance, adorned the top with a cornice and fastigium; then, as much of the joists as projected beyond the wall they sawed off, which, appearing unhandsome, they made tablets, like triglyphs now in use, fixed them against the sawed ends of the joists, and painted them in wax, that the sectures of the joists might not offend the sight. Thus, the triglyphs, interjoists, and opæ, in Doric work, had their origin from the disposition of the timbers of the roof.

"Afterward, in other works, some made the canthers, that were perpendicularly over the triglyphs, to project outward, and carved their projecture; hence, as the triglyphs arose from the disposition of the joists, so the mutules under the corona were derived from the projecture of the canthers; wherefore, in stone or marble structures, the mutules are represented declining, in imitation of the canthers; and, also, on account of the droppings from the eaves, it is proper they should have such declination.

"From this imitation, therefore, arose the use of triglyphs and mutules in Doric work; for it cannot be, as some erroneously assert, that the triglyphs represent windows; because triglyphs are disposed in the angles, and over the quarters of the columns, in which places windows are not permitted; for, if windows were there left, the union of the angles of buildings would be dissolved; also, if the triglyphs are supposed to be situated in the place of the windows, by the same reason, the dentils in Ionic work may be thought to occupy the places of windows; for the intervals between the dentils, as well as between the triglyphs, are called *metopæ;* the Greeks calling the bed of the joists and assers, *opas* (as we call it *cava, columbaria*); so, because the interjoist is between two opæ, it is by them called *met-opæ*. As the triglyphs and mutules in the Doric order are founded upon those principles, so the dentils, in the Ionic, derive their proper origin from the workmanship; and as the mutules represent the projectures of the canthers, the dentils in the Ionoic order are in imitation of the projecture of the assers."

This theory is a very plausible one, so far as it goes; and were we unable to account for such matters in a different way, it might be passed over as correct, but for one objection, and that alone at once throws discredit upon the whole account. The difficulty may be put in this way: if the prototype of the stone structure were constructed of timber, how comes it, that the proportions of the former are of so heavy and massive a character? and how is it, that the columns are so thickly set? Timber construction would have led to very different results; slenderness and lightness are the characteristics of buildings of such material, and so, necessarily, of its antitype. The reverse, however, is the case; and not only so, but we find, that the older the edifice, (and therefore the more similar to its prototype) the heavier, also, its proportions; whereas, if Vitruvius's theory be correct, the contrary should be observable. But, besides this, we can account for all the details alluded to by Vitruvius in a very different, and, to our mind, far more satisfactory manner, as we shall attempt to explain presently.

As regards the date of the introduction of this style of building into Greece, nothing can be stated with certainty; neither can it be satisfactorily ascertained in what locality it first appeared: great differences of opinion exist on both subjects. Vitruvius, as usual, decides the matter without any apparent difficulty. He says:

"The most ancient and first invented of the three kinds of columns is the Doric; for, when Dorus, the son of Hellenus, and the nymph Opticos, reigned over all Achaia and Peloponnesus, the temple of Juno, in the ancient city of Argos, was erected, and this order happened to be

used in the fane. The same order was also used in the other cities of Achaia before the laws of its symmetry were established.

"Afterward, when the Athenians, according to the responses of Apollo and Delphos and the common consent of all Greece, transplanted, at one time, thirteen colonies into Asia, apportioning to every colony a leader, they gave the chief command to Ion, the son of Xuthus and Creusa, whom also the Delphian Apollo acknowledged for his son. These colonies he conducted to Asia, seized on the territory of Caria, and there founded many large cities, as Ephesus, Miletus, Mynuta, (which last was formerly overflowed with water, and its rites and privileges, by Ion, transferred to the Milesians), Priene, Samos, Teos, Colophon, Chios, Erythræ, Phocis, Clazomenæ, Lebedus, and Melite. This latter, on account of the arrogance of the citizens, was destroyed in the war declared against it, by the unanimous determination of the other cities, and, in its place, by the favour of king Attalus and Arsinoe, the city of Smyrna was received amongst the Ionians. When those cities extirpated the Carians and Leleges, they, from their leader, Ion, called that territory Ionia.

"There they began to erect fanes, and constitute temples to the immortal gods. First, they erected the temple of Apollo Panionias, in the manner they had seen it in Achaia; which manner they called Doric, because they had seen it first used in the Dorian cities. In this temple they were desirous of using columns, but were ignorant of their symmetry, and of the proportions necessary to enable them to sustain the weight, and give them a handsome appearance: they measured the human foot, and finding the foot of a man to be the fifth part of his height, they gave that proportion to their columns, making the thickness of the shaft at the base equal to the sixth part of the height, including the capital. Thus the Doric column, having the proportion, firmness, and beauty of the human body, first began to be used in buildings."

The former part of this statement may or may not be correct, but if its credit stands upon an equal footing with that of the latter part, we shall not be justified in placing much confidence in it; for ere we can give credence to his opinion respecting the proportions of the order, we must suppose the men of that age to have been of a very different description to those of the present day.

If Vitruvius be correct in his supposition regarding the introduction of the order, we must suppose several temples to have been erected in this style before Homer's time, but, if so, it would appear strange that one, generally so minute in his descriptions of persons and places, should not have given us some description of them. It is true, that he alludes to three or four temples,—to those of Minerva at Athens and Troy, and of Apollo and Neptune at Delphi and Ægæa, respectively,—still he has not given any description of them, and leaves us entirely to conjecture: according to the account of Pausanias, the temple at Delphi was nothing better than a hut covered with laurel and branches. But if we discard the account given by Vitruvius, we shall not be much nearer the goal, having no data to work upon. If we allow the name of the order to give us some clue as to its origin, we are still in the same predicament, for many provinces bore the name of Doris; and at best, as Lord Aberdeen remarks, a name is often the least satisfactory mode of accounting for the birth of the thing which bears it. Many are of opinion that the order was first employed in the cities of Corinth, Sicyon, and Argos, shortly after the return of the Heraclidæ, but others suppose it to have originated amongst the colonists of Asia Minor, and there certainly does appear some reason for supposing that the temples here were far in advance of those in Greece-proper.

In whatever part of Greece the Doric order was first employed, there seems very good reason to believe that it had its origin in Egypt, or rather perhaps that the temples of that country suggested the idea; nor is there any *primæ facie* grounds for rejecting this supposition, for we know, in the first place, that Greece was, at least, to some extent, colonized from Egypt; Cecrops was from that country, and Cadmus from one not far distant; and besides this, we know that in after times the Greeks were in the habit of trading with Egypt, and were held in so great esteem by Amasis, that he gave them the city of Naucratis, and afforded them every encouragement and convenience. Another internal evidence of the connection of the two people is afforded in the identity of their mythology.

But let us consider the architectural features observable in the buildings of the two countries. In general appearance they agree; they are both of massive proportions, and both consist of similar parts, columns, entablature, and such like. Nor are they less similar in detail; in Egyptian temples we have an entablature consisting of three members, architrave, frieze, and cornice, the first of which, like the Doric, is comparatively plain, and the last simple, but bold. The similarity of the frieze in both styles is remarkable, extending even to triglyphs and mutules, and in both styles are those features equally essential. The similarity of the columns may not be at first so apparent, although we can point out many Egyptian columns without bases, with square plain abaci, and may suggest the probability of the Grecian echinus being copied from the lower portion of the bulging or cushion-capitals of Egypt: the annulets round the necking of the capital are likewise of very frequent occurrence in that country. As regards the rest of the column, it is true, speaking generally, that Egyptian specimens are not fluted, neither do they diminish, like the Greek, from the lower to the upper diameter; instead of concave flutes, however, we have convex rods, or probably reeds; and if the latter, we have only to divide them vertically down the centre, and we have the Doric flutes. But even if this last idea be too fanciful, the difference between a cabled and fluted column is not so great, the ornamentation is decidedly of a similar character; end even if this be disallowed, there are specimens of fluted columns in Egypt, and specimens which altogether bear a very marked resemblance to the Grecian-Doric. These columns were first noticed by Mr. Barry, who considers them of greater antiquity than any Grecian specimens. The first is a portico of two fluted columns in antis, about $5\frac{1}{2}$ diameters in height, and surmounted by a plain abacus; the flutes are 20 in number, and of shallow contour; the columns are without bases. The next example is from Kalaptchic on the Nile, the abacus of which is square, and 11 inches thick; the shaft, which has a trifling diminution, is 7 feet 8 inches high, and 3 feet 2 inches diameter. The circumference is in 24 divisions, whereof 4, which are at right angles with each other, are flat faces, covered with hieroglyphics, and the other intervening ones are sunk into flat elliptical flutes a quarter of an inch deep. Another specimen is to be seen at Amada in Nubia, consisting of two columns, one of which is a simple parallelopiped, and the other, at the corner of the building, is both cylindrical and fluted, leaving, however, a square abacus similar to that of the parallelopiped, which, in this case, is the only capital; the base is also of a square plan. Of these two columns, the former is evidently the earlier design, the latter, previously of the same shape, whether for convenience or otherwise, has been rounded off at the corners and somewhat ornamented.

Were it allowable to select portions from these examples and place them together at discretion, there would be no great difficulty in forming a very perfect specimen of Grecian-Doric, but even without such a metamorphosis, we suggest, there can be no difficulty in perceiving a great and indubitable similarity between the structures of Egypt and the earlier ones of Greece, the likeness being more striking in some examples than in others, yet not being entirely absent in any. We may conclude, therefore, we presume, that there is a very strong probability of the Doric order having been derived from the architecture of Egypt.

This order, as practised by the Romans and Italians, differs in some essential particulars from that above described, and in process of time its original character seems to have been all but entirely lost, the identity being evidenced only by the remains of some few details. The few points in which the resemblance between the Greek and Roman orders is preserved, are—the employment of triglyphs and metopes in the frieze, and of mutules in the corona, the fluting with arrises instead of fillets, when indeed flutes were introduced, and the general form of the capital consisting of echinus and abacus. The distinctions are much more numerous, amongst which may be mentioned the elongation of the shaft and the not unfrequent absence of flutes; the addition of a base, variations in the form of the capital and of the several members of the entablature, the amplification of mouldings and such like; so that were two examples, one of each kind, placed before a person unacquainted with the subject, he would have greater difficulty in tracing their resemblance, than in pointing out their incongruities.

The height of the column is increased from six to eight diameters, and in some cases, as recommended by Vitruvius for porticos, to eight and a half. It is either fluted or left plain, and sometimes is partially fluted, the channels extending about two-thirds of the shaft, the remaining portion below, from the base upwards, being left blank.

The addition of the base follows very naturally the elongation of the shaft, for were it still to be omitted, the lower portion of the column would look too small, and would give to the edifice an appearance of weakness; the columns would seem unsteady; whereas in the Greek examples, the massive proportions and the rapid spreading of the shaft from the capital downwards, gives the effect of strength and stability. The base generally used is that termed the attic, and consists of a plinth, a torus, a hollow moulding or scotia with a fillet above and below it, upon the uppermost of which is another torus and fillet, out of which the shaft rises with an apophyge; a simpler base, however, is sometimes made use of, comprising only a torus and two shallow fillets above it, and occasionally merely a plinth and simple fillet.

In the capital, the sunk annulets of the Greek examples are converted into projecting fillets in the Roman; the shaft is separated from the cap by an astragal which gives much greater distinctness to the necking, which again is sometimes relieved with rosets and buds, or other ornament. Above the neck are three flat annular fillets, and these above the ovolo surmounted by the abacus. The ovolo, however, is not of so much importance as in the Greek order, nor of the same severe contour; the abacus likewise is much shallower, and has the addition of mouldings on its top. The height of the capital is equal to $\frac{1}{2}$ a diameter, or 1 module, but this is not always the case, for in the Theatre of Marcellus at Rome, it is 33 minutes, and in the Coliseum as much as 38.

The architrave is often similar in appearance to the Greek, but is of less height, being equal to only two-thirds of the frieze, or half a diameter; in a few instances, the architrave is composed of two fascias. The new frieze is also very similar to the old one, with some slight exceptions, the mutules being frequently filled with ox-skulls and patteras, and sometimes left plain; the capitals of the triglyphs are of greater projection than before, and are returned at the ends. The triglyphs besides are in Roman examples, invariably placed over the centre of the columns, so that the ends of the frieze are finished with half-metopes, and not with triglyphs as in the Grecian order. In the Coliseum, the triglyphs are entirely omitted.

The cornice differs considerably from the Grecian, having its soffit flat and the mutules square, with a similar interval between them. In Grecian examples, the guttæ generally appear in front below the mutules; but in the Roman, they do not so, and are sometimes even omitted; sometimes the mutules entirely disappear, as in the Theatre of Marcellus, where dentils with an ogee bed-mould are substituted in their place, and the Basilica at Vicenza, designed by Paladdio, has merely a bold ogee and ovolo in their place. The intervals between the mutules are frequently enriched with panels and sculpture. The mutules and band are surmounted by a small ogee moulding, and under them is an ogee or ovolo forming a bed-moulding. The mutules support the cornice-proper, consisting of the corona, an ogee and fillet, and a cavetto finished at the top with a fillet.

With Vitruvius's account of the order, we conclude this article; it runs as follows:—

"Some architects," says he, "have maintained that temples should not be built of the Doric order, because it occasions an imperfection and an inconvenience in the symmetry; for this reason it was rejected by Tarchesius, Pytheus, and also by Hermogenes: the latter, after he had prepared marble materials for a Doric temple, altered them, and from the same materials, raised an Ionic temple to Bacchus. However, it was not because the appearance was unhandsome, or the manner or form ignoble; but because it impeded the distribution, and the arrangement of the triglyphs and lacunars was unsuitable to the design; for it is necessary that the triglyphs should be disposed over the middle quarters of the columns; the metopes which are between the triglyphs, be made as long as high; and the triglyphs over the angle columns he placed at the extremities, and not over the middle quarters. So that the metopes which adjoin the angular triglyphs, are not square, but more oblong by half the breadth of a triglyph. Those who would make all the metopes equal, contract the extreme intercolumn half the breadth of a triglyph; but this, whether it is done by lengthening the metope, or by contracting the intercolumn, is a defect. On this account, the ancients avoided the use of the Doric order in sacred edifices. Following, however, our method, we shall give the explanation of this order, as we have received it from the masters; so that those who attend to these precepts will here find described the rules by which they may erect a temple in the Doric manner, without fault or imperfection.

"The front of the Doric temple, where the columns are erected, is, if tetrastyle, divided into 28 parts; if hexastyle, into 44. Of these parts one will be a module, called in Greek, embates, by which the distribution of the whole work is regulated. The thickness of the column is two modules; the height, including the capitals, 14. The thickness of the capital one module, the breadth two and the sixth part of a module. The thickness of the capital is divided into three parts, of which one is for the abacus with its cymatium, another for the echinus with its annulets; and the third for the hypotrachelion. The columns are diminished in the same manner as described for Ionic columns in the third book.

"The height of the epistylium with the tenia and guttæ is one module. The tenia is the seventh part of a module.

The length of the guttæ, under the tenia, coincides with the perpendicular of the triglyphs. Their height, with the regula, is the sixth part of a module. The breadth of the bottom of the epistylium answers to the hypotrachelion at the top of the columns.

"Upon the epistylium, the triglyphs, having the metopes between them, are placed; being one module and a half high, and one module broad in front; they are so distributed, that those which happen over the angle, as well as over the intermediate columns, may be perpendicular to the middle quarters thereof; two are left in the intercolumns; and in the middle intercolumn of the pronaos and of the posticus, three; for, by this enlargement of the middle interval, the approach to the image of the god is rendered more commodious and free from impediment.

"The breadth of the triglyph is divided into six parts; of which, five are placed in the middle, two and a half being on either side. The middle one makes the regula, or femur, which the Greeks call meros. On either side this, are the channels, sunk as if imprinted with the elbow of a square. To the right and left of these, another femur is formed, and at the extremities, semi-channels are slanted.

"The triglyphs being thus disposed, the metopes, which are between the triglyphs, are as high as long. At the extreme angles, semi-metopes are impressed, half a module broad. Thus, the metopes, intercolumns, and lacunars, being regularly distributed, all defects will be avoided. The capital of the triglyph is made the sixth part of a module.

"Over the capital of the triglyphs, is placed the corona, projecting the half and the sixth part of a module, having a Doric cymatium below, and another above. The thickness of the corona, with the cymatiums, is half a module. In the under part of the corona, perpendicular to the triglyphs, and to the middle of the metopes, the directions of the viæ, and the distribution of the guttæ, are to be so contrived, that there may be six guttæ in length, and three in breadth. The remaining spaces (the metopes being broader than the triglyphs) are left plain, or have the sculptures of thunderbolts. Near the edge of the same corona a line is enchased, which is called scotia. The tympan, sima, corona, and the rest, are executed in the same manner as has been described for the Ionic order.

"The foregoing is the method for composing diastyle works; but if the structure is to be made sistyle and monotriglyph, the front of the temple, if tetrastyle, is divided into twenty-three parts; if hexastyle, into thirty-five. Of these, one part will be a module, by which the work is to be regulated, as before written. Then, over every epistylium, two metopes and triglyphs are disposed. In the angles, this species is larger than the former by as much as the space of the bisected hemitriglyph. So that there happens in the middle epistylium, under the fastigium, the space of three triglyphs and three metopes, for the enlargement of the middle intercolumn renders the entrance of the temple more spacious, and gives an appearance of dignity towards the statue of the god.

"Upon the capital of the triglyphs the corona is to be placed, having, as before said, a Doric cymatium at bottom, and another at top. The thickness of the corona, with its cymatiums, is half a module. The under part of the corona, perpendicular to the triglyphs and to the middle of the metopes, is to be divided, for the direction of the viæ, and the distribution of the guttæ; all the rest are the same as has been mentioned in the diastyle species.

"The columns are to be wrought in twenty striæ, which, if made flat, form twenty angles; but if they are hollowed, they are to be thus performed: A square is described whose sides are equal to the interval of a striæ; in the centre of the square, the central point of the compasses is placed, and a circular line drawn touching the angles of the square; and that portion of the curve which is between the lines of the circle and the square, forms the hollow of the striæ. Thus, the Doric column will have its proper kind of striature. With regard to the swelling which it has in the middle, it is the same as has been described for Ionic columns."

To exemplify this order, and illustrate the true Grecian Doric, we have chosen that beautiful specimen from the magnificent portico of the Parthenon, at Athens, exhibited in *Plate* I.: the proportions are numbered in minutes, in the usual way. The outline exhibits the profile of the flank, and the finished order shows the profile on the front of the portico, adjoining that represented by the outline.

Plate II.—Outline of the modern Doric.

Plate III.—A finished plate of the same, from Sir Wm. Chambers, who took his example from Vignola.

Plate IV.—Roman Doric, from the theatre of Marcellus, at Rome; showing both the outline and finished plate.

DORMAN, a cross beam.

Dorman-Tree, a joist, or sleeper.

DORMANT, or Dormer, a window made upon the sloping plane, or side of a roof, with a glass frame perpendicular to the horizon.

Dormer windows occur frequently in domestic edifices of the Gothic style, in which they form a very picturesque feature. Their frequency is especially remarkable in the old halls, &c., of France and Flanders.

Dormant-Tree, see Summer.

DORMITORY, a sleeping room.

DORON, the Grecian palm, whence their bricks were called *tetradoron*, and *pentadoron*.

DOS D'ANE (French), an obtuse ridge, formed by the intersection of two inclined planes. The term is synonymous with our word, coped.

DOSEL, or Doser, a rich hanging of tapestry or other stuff, or screen of ornamental woodwork employed to decorate the back of an altar, throne, &c.

DOUBLE VAULT, two vaults of brick or stone, carried up separately, and including between them a hollow or cavity, such as that of St. Peter's, at Rome.

DOUBLE BUILDING, one in which the walls are carried up double; sometimes cellars are carried up with double walls, and double vaults, so as to include a cavity of air in order to keep the wine cool.

DOUBLE COLUMN. *See* Column.

DOUBLE CURVATURE, the curvature of a curve, of which no part can be brought into a plane, such as the cylindro-cylindric curve, &c.

DOUBLE DOORS, those where two doors are made in the same aperture, in order to keep the apartment warm. *See* Door.

DOUBLE FLOOR, one constructed of binding and bridging-joists. *See* Floor.

DOUBLE-HUNG SASHES, are those where the window consists of two sashes, each of which is moveable by means of weights.

DOUBLE MARGIN DOOR, that which represents two doors in the same breadth, but is, in fact, only one door. *See* Door.

DOUBLE TORUS. *See* Moulding.

DOUBLE WINDING STAIRS. *See* Stairs.

DOUBLING, the same as eaves-boards; the term is used in Scotland.

DOUCINE, or DOUCHINE, (from the French), the *sima-recta.*

DOVE-COT, a small building or box in which domestic pigeons breed.

DOVE-TAIL, in joinery, a piece of wood formed like the tail of a dove.

DOVE-TAILING, the method of fastening one piece of wood to another, by projecting pins, cut in the form of dove-tails in one piece, and let into hollows of the same form in the other. Dove-tailing is either exposed or concealed; concealed dove-tailing is of two kinds, lapped and mitred.

DOVE-TAIL MASONRY. *See* MASONRY.

DOVE-TAIL MOULDING. A moulding used in Norman buildings, so called from the shape of the running ornament employed in its decoration, which consists of a fillet, tracing in its progress the form of a dove-tail, the alternate dove-tails being inverted, and having one side common to both.

DOVE-TAIL NOTCH, a *common* dove-tail notch is that where the bottom is in the form of a trapezoid.

An *undercut* dove-tail notch is that where the bottom is a parallelogram of greater breadth than the width of the parallelogram cut out of the surface; the excess in breadth being alike on both sides.

DOVE-TAIL SAW, a saw used for dove-tailing. Its plate is about 9 inches long, and has about 15 teeth in every inch; a rigid iron or brass back is added, to give stiffness to the plate.

DOWEL, the pin or tenon used in joining together two pieces of any substance. This pin or dowel is of wood or iron, and is thus used. Holes corresponding to each other are made in the boards to be joined; one-half of the pin is inserted into the hole in the one piece, and the other piece is then thrust home on it.

DOWELLING, or DOWELING, the fastening together two boards by the method above described.

DRAG, a term applied to anything bearing down, or rubbing upon another; thus, a door is said to drag, when its hinges are so loosened, that the lower edge rubs upon the floor: and the term is also applied in masonry to a thin plate of steel indented on the edge, used for finishing the dressing of soft stone which has no grit.

DRAGON-PIECE, a beam bisecting the wall plate, for receiving the heel or foot of the hip-rafters. It is most commonly a very short piece of timber, fixed at right angles into another piece, called the *angle-tie*, or *diagonal-tie*, which is again supported by each adjoining wall-plate being cocked down thereon.

DRAGON-BEAMS, according to Neve, are said to be "two strong braces or struts, that stand under a bressummer, meeting in an angle under the shoulder of a king-piece." —Neve's *Builder's Dictionary*. The writers of the present work have never heard the term applied to story-posts and bressummers, nor have they been able to learn any such application of it; the word *beam* is improper for any piece of timber, that stands slanting as a brace or strut. Neve's *Builder's Dictionary* was an original work; and it is probable that the author, who subscribes himself "Philomath," (a lover of learning) instead of architect, carpenter, joiner, mason, &c., might have been misinformed by the workmen, among whom he made his inquiries. The *Builder's Dictionary*, in two volumes, was copied from Neve, as was the *Dictionary* of the first volume of the *Builder's Magazine;* and we may farther add, most of the Cyclopædias and Encyclopædias have applied the term in the same way as Neve, and have used the same words in describing it. But with regard to the application of the term *dragon-piece*, as it is defined above, we can refer the reader to the oldest books that are published; see page 230, in the *Rules for framing roofs*, at the end of Godfrey Richards' *Palladio*, where that author says, "3. Dragon-beams for the hip to stand on," and immediately following, he says, "4. Beam or summer, wherein the dragon-beams are framed;" referring at the same time to *Figure* c, or Plate c; see also our review of carpentry, at the end of Godfrey Richards' *Palladio*. The sense in which Godfrey Richards uses the term, is the same as that now in use. It is true, that Moxon explains dragon-beam in the same way as Neve, but he refers to no figure. The second edition of Godfrey Richards' *Palladio* is dated 1676, and the first edition must be much more early. The first edition of Neve's *Builder's Dictionary* is dated 1703; we have also the corroboration of Batty Langley, see *Plate* II. of the *Addenda*, consisting of fourteen plates of roofs, at the end of his designs, where he says, "*a e, b e, c e, d e*, dragon-pieces to receive the feet of the hip-rafters" so that Godfrey Richards and Batty Langley apply the same meaning to the term. We have been thus particular, because a proper explanation of the word, as it is used, has not been given, and to show that it is an injury to a work, to describe a term which has no existence, or, if it has, must be confined to some remote corner.

DRAIN, a subterraneous passage for water. If a building is obliged to be erected in a damp soil, it will be proper to drain the ground before the foundation is laid. In large buildings, there must be one principal drain, and several smaller ones, depending on the extent of the ground; and observe, that those with circular bottoms are better than those which have straight ones, as the water will run much deeper in the former, than in the latter, and will consequently clear away the sediment much easier. The large drain ought to be of sufficient height to admit a person to clean it with ease. Circular, barrel, or cylindric drains, are much stronger than common drains, in which the sides are formed by vertical walls. *See* DRAINAGE and SEWERAGE.

DRAINAGE. As we shall have occasion to treat this important subject at some length, and as, in so doing, it is desirable to consider the question both in its more comprehensive and general sense, as well as in its details, we shall refer the reader to the article SEWERAGE. Under that head, we shall enter fully into the various methods of house drainage, as suggested by the improved knowledge of modern times, and describe the extensive works which have been constructed for this purpose in the metropolis. See CLOACA, SEWER, SEWAGE.

DRAUGHT, in architecture, the representation of a building on paper, explanatory of the various parts of the exterior and interior, by means of plans, elevations, and sections, drawn to a scale, by which all the parts are represented in the same proportion as the parts of the edifice intended to be executed. All the horizontal parts are explained by plans; the faces of the vertical parts are represented by elevations and sections; particularly, when the plane of delineation is parallel to the faces to be represented. The vertical dimensions of buildings upon circular and polygonal plans are understood from the elevations and sections. In complex buildings, besides the general plans, elevations, and sections, a set of drawings should be made to show the detail of the small parts.

In addition to the drawings which are used in conducting the work, a perspective representation of the exterior should be furnished by the architect, in order to show the general appearance and effect of the intended edifice to the employer, and perhaps, in some instances, two or more perspective representations will be necessary, in order to bring more parts into view, which should be drawn to such points as those in which the building will be most generally seen.

When several stories of a building differ in their construction, each story requires a separate plan. The sections are generally parallel to the sides of the edifice, taken through the most complex or principal part. Most buildings require at least two sections, some many more. When the sides of a building are dissimilar, as many elevations will be necessary as the edifice has sides.

The number, the form, and disposition of rooms are shown by the plans. The architect who gives the design of a building, ought to be well acquainted with the constructive parts of carpentry, masonry, and bricklaying, before he commits his ideas to paper, or otherwise he may be liable to public censure. See DESIGN.

DRAUGHT, in mechanics, the force or power necessary to move any machine, as a horse-mill, waggon, cart, plough, &c.

DRAUGHT, in carpentry and joinery; when a tenon is intended to be pinned to the cheeks or sides of a mortise, and when the hole through the tenon is put nearer to the shoulder than the holes through the cheeks of the mortise from the abutment, which receives the shoulder of the tenon, or which comes in contact with the shoulder of the tenon, the pin is said to draw, or have a draught.

DRAUGHT, in masonry, a part of the surface of the stone hewn to the breadth of the chisel on the margin of the stone, either according to a curve or straight line, as the surface of the stone is to be reduced to a plane or curved surface. When the draughts are formed round different sides of the stone, the intermediate part is wrought to the surface, by applying a straight-edge or templet. In large stones, particularly when the substance is required to be much reduced, sometimes several intermediate parallel draughts, dividing the stone equidistantly in its length, are made, and thus the intermediate parts may be hewn down nearly by the eye, without the application of the straight-edge or templet.

DRAUGHT COMPASSES, those provided with several moveable points, to draw fine lines in architecture. See the words COMPASS and MATHEMATICAL INSTRUMENTS.

DRAW-BORE, when a mortise and tenon is intended to be pinned, by piercing the hole through the tenon, nearer to the shoulder than the holes through the cheeks from the abutment, in which the shoulder is to come in contact, the mortise and tenon is said to be draw-bored: see the following word.

DRAW-BORE PINS, pieces of steel, made in the form of the frustum of a cone, but rather taper, and inserted in handles, with the greatest diameter next to the handle, for driving through the draw-bores of a mortise and tenon, in order to bring the shoulder of the rail close home to the abutment on the edge of the style; when this is effected, the draw-bore pins, if more than one be used, are to be taken out one at a time, and the holes immediately filled up with wooden pegs.

DRAW-BRIDGE, in general, a bridge constructed of several boards nailed or bolted to a frame. This being fastened at one end, by means of strong hinges, to a beam laid horizontally, and parallel to the frame, and being acted upon at its other extremity by levers, or by chains, worked either by wheels or by hand; the platform thus constructed may be raised to a perpendicular direction. Drawbridges are usually placed over narrow ditches, in fortresses, at the ends of great bridges, and especially over the excavations close to the gates, so that they may be raised or let down at pleasure.

When drawbridges are made close on the outside of the gates, the masonry ought to be sunk so as to admit of the whole depth of the frame to lie within it; else the oblique fire from the besiegers' batteries would act on the edge of the frame, and soon render it unserviceable. In canal navigation, and in wet docks, swing bridges, that turn horizontally upon one end as an axis, have almost wholly superseded draw bridges. See IRON BRIDGE.

DRAWING, in its strict meaning, may be defined as the art of representing objects, on any convenient surface, by lines describing their form and contour. This is independent of colour, and even of shadow; because, notwithstanding form may be expressed by outline alone, shadow, while giving surface and substance, must be dependent upon form, and, in many cases, requires to be accurately defined according to the rules of perspective.

Before proceeding to describe the process of ordinary architectural drawing, we shall venture to insert some caustic, though just observations of Mr. Bartholomew, on this necessary study.

"There is no small boasting, in the present day, of architectural drawing. An architect cannot draw too well; but when he obtains much practice, he will find, that, besides designing the form and the details of his works, he has little time for drawing; in general, he has as little time for making the clean and fair copies of his drawings as the sculptor has for the stone-cutting department of his art; while, if he cannot design, and is unacquainted with the other many branches of knowledge which he should possess, he should cease to call himself an architect.

"In making drawing his sole study, (but with the interruptions which business will naturally bring,) the pupil becomes only a bad artist, and no architect at all. The pernicious folly of imagining, that he who can make an architectural drawing must of necessity be able to make an architectural building, has wrought largely towards the ruin of real architecture, and has tended more than any thing else to fill our metropolis, and other places, with white-washed and even stone ruins, which the weak have mistaken for architecture, and has led to that general disregard to structural propriety, which is the besetting sin of modern works.

"Now, the time spent in learning to draw badly; a work without truth, without philosophy, without art, without structural excellence, without geometrical ground-work, without adaptation to its purpose, without real beauty, either abstract or obvious; this time, so misemployed, might have been successfully employed by him (were architectural education such as it should be) in, by the age of twenty-five or thirty years at the utmost, learning thoroughly all the known arts of trussing, of roofing, of vaulting, of doming, of framing arches, pyramids, and all other parts of architecture in structural perfection. This safe ground-work, with the necessary growth of mind, expansion of power, freedom of ability, would lead the professing architect to soar aloft, over all the chained spirits who fancy a few water-colours alone can raise them above San Micheli and Palladio—above Wren and Chambers. They know they cannot surpass Raffaello and Buonarotti in drawing; yet they do not consider that they might with ease surpass them both in architectural design and construction: thus they choose that competition in which they cannot succeed, and neglect the one in which they might gain an easy victory. They might be the first of architects, but they choose rather to be the last of artists: instead of gazing with an astonished ignorance upon ancient buildings, they might as much surpass them as the science of the moderns surpasses that of the ancients."—'Bartholomew's Specifications for Practical Architecture.' However severe these strictures may appear, there is great truth in them, and they deserve the serious attention of the student.

Drawing is the basis of architecture, engraving, and painting; and may be divided into outlines and shadowing. The outline, or contour, represents the boundaries of an

object, as they appear to terminate against the back ground; the outline, as its name implies, takes in all the parts of the body. The interior parts are marked by lines, if such be distinct on the body, and the different inclinations of the surface are defined by depth of colour, in proportion to the inclination.

In fanciful objects, whatever the figure may be, the general form should be first sketched out slightly, that what is found to be amiss may be more easily removed, and corrections more easily made. Estimate as nearly as you can the principal points of the original, and fix dots at proportional distances, disposed at equal apparent angles on your paper; then draw your lines carefully to them, beginning at the upper part, and working either from the right to the left, or in the contrary direction, according to their tendency downwards. Put in the divisions first, and when these are nearly right, mark in the smaller parts; then, having got your work altogether, examine it scrupulously, rubbing it gently with a piece of bread, in order to render the lines more obscure: revise and correct the whole as often as it may be found necessary. Compare all the parts of the copy with the original, in every direction, first horizontally and then vertically, from a given point, which may be supposed to be the centre of the picture.

Beginners should make their drawings of the same size as the original, in order to exercise the eye in measuring with exactness; after some practice, however, it will be better to vary the size from the original, in order to acquire the habit of estimating distances, that, when combined, will form parts, similar to the whole, as also to the whole mass or general contour.

After the outlines are finished, the learner may proceed to the shadows; the first lesson should be simple, only indicating the principal projections. The simplest method of forming these is, by repeated lines nearly parallel to the outline, and as he advances with more shades, these lines should be crossed by other equidistant lines. This manner of sketching constitutes that peculiar manner of drawing called *hatching*, a mode very well calculated to give freedom of hand in any style of drawing. The chief things to be attended to are, that the lines conform as much as possible to the original, bearing all their inflections in the same ratio; the intersections should not be too violent, nor the lines so strong as to have the appearance of net-work.

In architectural drawing, the shadows are made out by washing or tinting the paper with Indian ink, sepia, or bister, laid on with a camel-hair pencil: this may be done in two different ways; the one is by laying down the shades as nearly in their places as possible, with tints sufficiently dark, and softening off the edges with a clean pencil and water, and when dry, the process may be repeated again, as often as may be found necessary; the other is by working with very light tints at first, in blotches placed near each other, then blending these by a faint wash over the whole, and when nearly dry, strengthening them by filling up the interstices with other blotches: thus, by repeated blotches, the surface will acquire the degree of tint required in the various parts. This mode is called *stippling*, and in the hand of an artist is perhaps the best, at least for finished drawings. In the shadows of anything projecting from a surface, we shall, for the sake of example, suppose a pole projecting from the surface of a wall, at a considerable distance from it; the outline of the shadow next to the foot of the pole will be very dark and definite, but in proceeding towards the extremity, the edge becomes more penumbral, and at last, in a very extended shadow, is hardly definite. All shadows are darker nearer to the body than those which are more remote; attached columns and pilasters will throw a stronger shadow than insulated columns upon the wall behind, and the projections of the shadows of insulated columns will be darker, and more defined upon their edges, than those which are placed at a greater distance from the wall, and, again, the middle part of the shadows will be darker than the edges.

The shadow of a plane figure falling upon a plane parallel to it, will form a figure similar and equal to that which throws it, as the shadow of all lines on a plane, parallel to these lines, will also be parallel to the same lines which project them. Besides what has been already hinted above, there is another method, which is excellent for mouldings, particularly when small, viz., to use very little ink in the pencil; let us, for example, suppose we were to shade a moulding: take the camel-hair pencil with so little ink that it cannot run, or that it will dry the instant it is put on the paper, and run it the whole length of the moulding, upon that part which requires to be the darkest; then repeat the process in the same manner, by making the tint broader, or to spread farther over; repeat in this manner, by making the last tint spread over each edge of the preceding, keeping the edges of every tint as straight and parallel as possible, until the moulding has acquired its full variety of tints, so as to represent all the various inclinations of the original surface. If any part appear too light, it is only necessary to go over that part again, touching only the part that is too light. Or, the learner may begin the reverse way, by making the broad tints first, and proceed to make narrower and narrower tints each time.

In shadowing a cylinder of considerable width, begin at the line of demarcation of light and shade, where a plane from the luminary would touch the curved surface in a straight line of contact, and having gone the whole length of this line with a tint, soften the edges with water. Proceed in the same manner the second time with a broader tint, covering the edges of the former, and washing off the edges as before, thus continually spreading each repeated tint, until you come to the line of light, viz., where a plane extended from the luminary to the axis of the cylinder, included in the plane, would cut the surface of the cylinder. Then from the opposite edge of the representation of the cylinder, lay a light tint close to the line, as narrow as it can be put on, and soften the edge of it next to the line of light; lay a broader tint next time, and soften the edge in like manner, next to the line of light; proceed in this manner, until you come again in contact with the line of light; observing, that the depth of colour in receding from the line of light in the parts which represent equal distances, should be the same, or of an equal degree. In washing towards the line of light, the washes must be lighter and lighter, as too much colour will destroy the delicacy necessary to be preserved in the light part. If, after all, any part should appear to be too light, the defect may be made up by tinting that part only, with very little ink in the pencil. For other information, concerning the manner of preparing the tints, we shall refer to the article SHADOWING.

DRAWING-KNIFE, an edged tool, made sharp at the end, for cutting a deep incision into the wood, along a straight-edge, the edge of a square or templet, in order to enter the saw without ragging the wood. A chisel or firmer is sometimes used instead of the drawing-knife. In joinery, the drawing-knife is useful in rebating across the grain, cutting the shoulders of tenons, grooving across the fibres.

DRAWING-ROOM, a principal apartment of a great mansion, or nobleman's house, to which it is usual for company to withdraw after dinner, and in which formal visits are received. *See* DINING-ROOM. In small houses, the draw-

ing-room may communicate with the dining-room, but in large houses, it will be no detriment, and might even be preferred by many, if the library, or an ante-room should intervene. The term is frequently written *withdrawing-room.* *See* Room.

DRAWING-SLATE, a soft stone of fine grain, used as a marking or drawing material. It is sometimes called *black chalk.*

DRAWINGS, *Working, See* Working Drawings.

DRAWN through or along the Axis, or through or along a straight Line, is when a plane meets a straight line, so that all parts or points in the line are also in the plane.

DREDGING. The operation of removing mud, silt, and other depositions from the bottom of harbours, canals, rivers, docks, &c., by means of a Dredging Machine.

DRESS, in masonry, to prepare stones for building.

DRESSED, the preparation that a stone requires before it is ready to be used in building, &c. Stones are dressed sometimes by the hammer only, thence termed hammer-dressed; sometimes by the mallet and chisel, the face afterwards being rubbed smooth. In Scotland the term is only understood of hammer-dressing.

DRESSER, a kind of bench or table, with drawers, set in the kitchen, used for culinary purposes: it is generally reckoned as a fixture of the building, or a part thereof.

DRESSING-ROOM, a room adjoining a sleeping-room, used for dressing in, as its name implies. A dressing-room ought to have two doors, one to communicate with the sleeping-room, and another to communicate with the passage, for the valet, or servant.

DRESSINGS, all kinds of mouldings projecting beyond the naked of walls or ceilings, are called by the general name of *dressing*. In joinery, the architraves of apertures, or other appendages, as also the projecting moulding used as a finish, is called *a dressing*, and frequently *facing*.

DRIFT, the horizontal push or force, which an arch exerts from the gravitation of the stones, which are kept from descending by the inclination of the beds of the arch, and the resistance of the pier. The terms *shoot and thrust*, are also employed to express the same idea.

DRIP, the edge of a roof; the eaves; the corona of the cornice. *See* Larmier, Corona.

DRIPPING EAVES, when the slope of a roof is continued downwards, so as to project over the roof of a building, the part thus projecting over is called *dripping eaves*, in contradistinction to those roofs that have blocking courses, which run above the slope of the roof, and which have gutters behind for carrying off the water. Dripping eaves are prohibited, in the city of London, by the Building act.

DRIPS, steps made in flat roofs, to walk upon. This way of building is much used in Italy, where the roof is not quite flat, but a little raised in the middle, otherwise the steps would have no rise.

DRIPSTONE, the projecting moulding or cornice over windows, doorways, &c., is called a dripstone. Its use is to throw off the rain, and in some of the old buildings in the country, it has been made of an ornamental character. The dripstone is of various forms, and when a head is not used as a termination or support, a simple moulding is adopted. It is also called label, weather-moulding, and water-table.

The term *dripstone*, however, is more particularly applied to the boss at the termination of the moulding from which the rain drips, after being conducted down the moulding; the latter is distinguished by the appellation of *weather-moulding.*

DRIVER, *Pile. See* Pile Driver.

DROPS, in architecture, small pendent cylinders, or the frustums of cones attached to a vertical surface, the axis of the cylinders or cones having also a vertical position, and their upper ends attached to a horizontal surface.

Drops are used in the cornice of the Doric order under the mutules, and in the architrave under the triglyphs. Each mutule has three rows from front to rear, with six drops in each row, disposed at equal distances, in lines parallel to the front. The drops upon the architrave are also six feet under each trigylph, disposed also equidistantly. Drops in the form of frustums of cones, are only peculiar to Roman architecture, and to some of the temples of Pæstum; there are some Grecian-Dorics, however, wherein the drops in their vertical section have the upper part nearly parallel, and terminate below with a concavity, the part above being a tangent to the curve. In the Roman-Doric, the surface of the metopes is the same with that of the architrave, and the vertical surface of the trigylph projects at the same distance as the drops, which are hung from the tenia. In the Grecian Doric, the faces of the triglyphs are generally disposed in the same vertical surface with the face of the epistylium, and consequently, the regula and drops pending therefrom project. The Doric portico at Athens, the portico of Philip king of Macedon, and the temple of Apollo in the island of Delos, are instances wherein the surface of the epistyle is within the surface of the triglyph; but it is to be observed, in the two latter examples, that there is a drop in each angle common to every return face. All examples of the Doric order, except the portico of the Agora, or Doric portico, at Athens, have the sides of each extreme drop under the regula in the same vertical line as each edge of the triglyph above, and the whole six drops are contained within the perpendiculars, by producing the edges of the triglyphs.

In all the drops of the Doric architraves to be met with, the horizontal sections are circles, increasing towards the bottom of the drops, or of a cylindrical form, except in the instance of the temple of Apollo at Cora, in Italy, where the soffits of the drops in the architraves are inclined. It is singular, that in this example, the drops pending from the corona are continued equidistantly without interruption in three rows, two behind the front row; and that those pending from the corona are perfectly cylindrical, with level soffits, while those pending from the regula are conical, and have inclined soffits, which form an obtuse angle with the face of the epistyle. In the choragic monument of Thrasyllus, the tenia of the epistylium has a continued row of drops, but this example cannot be accounted a Doric order, having no other peculiarity to the Doric composition.

The drops pending from the soffits of the mutules, have their soffits in a plane parallel to the soffits of the mutules, and consequently, inclining; while those of the epistyle have their soffits in a horizontal plane.

The height of the drops in the cornice of the Doric portico at Athens, is little more than one quarter of their diameter, while those of the epistyle have their height more than half their diameter.

In the peripteral temple at Pæstum, the corona has no pending mutules, nor any drops. In the theatre of Marcellus at Rome, there are no mutules, the interstices between the drops are formed by excavating upwards into the soffit of the corona, and are covered on the front with a moulding, which has its soffit in the same inclined plane with the soffits of the drops, so that the drops show no geometrical elevation. In the enneastyle, or nine-column temple at Pæstum, the cornice is destroyed, and the architrave seems to have been originally without either mutules or drops.

The term *guttæ* is also applicable to what we have called *drops*.

DROVED ASHLAR, a term used in Scotland for chiseled, or random-tooled ashlar. It is the most inferior kind of hewn work used in building. It is true, that what is there called broached work, is sometimes done without being droved, but in good broached work, the face of the stone should be previously droved, and then broached. See the article MASONRY.

DROVED AND BROACHED, a term used in Scotland, in a more specific manner than that of broached work; see the preceding word.

DROVED AND STRIPED, work that is first droved and then striped: the stripes are shallow grooves done with a half or three-quarter inch chisel, about an eighth of an inch deep, leaving the droved interstices prominent. These kinds of hewn work are not used in England, or at least very seldom; the work is either regularly tooled, or rubbed smooth.

DRUIDICAL TEMPLE, stone pillars, arranged in the circumference of the circle, surmounted with an architrave or entablature, such as Stonehenge. *See* CELTIC ARCHITECTURE.

DRUM, a cylinder, generally formed of cast-iron, but sometimes of wood, and used on the inclined planes of railways, for receiving the rope which is wound round the surface of its periphery, by which movement the waggons are conveyed along the line. Drums are used when the plane is worked by a single rope.

DRUM, of the Corinthian and Composite capitals, the solid part, in the form of a vase, to which foliage, stalks, and caulicoli are attached. The drum is otherwise called *vase*.

DRUM. *See* DOME.

DRY-ROT, a highly destructive vegetable disease, affecting the timber in the foundations, and other parts of buildings, in particular soils and situations. It affects the wood, or ligneous parts, in such a manner, as to leave it connected by nothing but the small hard fibrous portions, which give it a curious tremulous appearance, but all of which, when touched by the hand in the more advanced stages of the disease, readily moulder into a brownish snuff-like dust. It is attended with a peculiar earthy smell, similar to that which issues from wood fresh dug up after having lain some time in the ground in contact with decaying animal matter, and is materially different from that natural sort of decay which takes place in wood from the presence of wetness.

On the causes of this decay numerous volumes have been written, and equally numerous have been the nostrums for its prevention or "cure." There can be little doubt that, in very many cases, dry-rot has been engendered by the extreme wetness of the timber, caused by its long immersion in the water, in docks, canals, &c. In our hastily-constructed buildings, the timber, after having been thus swelled by soaking too much beyond its former and its ultimate bulk, is frequently framed together while in this wet state, and it cannot be surprising that the dry-rot soon appears as a natural consequence of such unwise proceedings.

It has been said, that moist and warm situations, where the circulation of the air is impeded, is the generating cause of this disease; that the effluvia from timber so diseased, will carry their effects to the circumjacent timber; and that any sort of wood, dry as well as damp, so exposed, will be soon destroyed. Timber once infected cannot be restored, and the only remedy lies in cutting away the diseased parts, to prevent the extension of the evil to the remainder; and to effect even the latter, a free circulation of air must be admitted, and the parts be washed over with a strong solution of iron, copper, or zinc. Patents have been granted for various applications of the latter, as preventives of the dry-rot, the distinguishing features of the processes therein employed consisting in first preparing the timber by a good steaming, or drying out of the sap, and afterwards injecting, soaking, or boiling the timber in a solution of copperas, or other metallic salt. The following observations on this important subject were some time since addressed to the editor of the "Engineers and Mechanics' Encyclopædia," by Mr. John Gregory, who is an experienced and observant shipwright; and as they appear to mark out clearly the true cause of, and to suggest a very simple remedy for, the evil, it is right to give them a place in this work. Mr. Gregory says, "Instead of squaring a piece of timber according to the usual method, by leaving the heart of the tree in the centre, my plan is to saw it right down the middle, through the heart, into two equal parts, immediately after the tree is felled; and my reasons for this I will now endeavour to explain, to the best of my ability. It is, I believe, a well-known fact, that a tree does not, literally speaking, *die* on receiving the final stroke of the axe, but that it continues for a long period afterwards to vegetate, though less vigorously. At length, however, the sap ceases to circulate, the pores become closed, and the juices of the tree thus shut up undergo decomposition, and lay the foundation of dry-rot. It is well known, that a man, who dies in a full habit of body, soon decays; the same effect takes place in a tree full of sap, unless we adopt the same method with respect to it as the Egyptians practised with the human body, viz., that of depriving it of all moisture, which process would give to our timber a durability almost everlasting. My mind has been long impressed with this idea, which has been confirmed by my having recently noticed, that several of the timbers, in a very ancient public building, which had been sawn originally in the manner I have proposed, were *perfectly sound*, although they had withstood the dilapidating hand of time for seven hundred years; while other timbers in the same building, which had not been so cut, but apparently squared out with the heart in the centre, were perfectly rotten. That the dry-rot is certainly caused by the juices being enclosed in the heart of the timber, I have had frequent opportunities of observing during my long practical experience in the repairing of ships. In the frame of a ship in which such large quantities of timber are employed, I have uniformly noticed: First, that the decay commences in the run fore and aft, which is owing to the timbers being fitted so close together at the heels or lower ends. The evil being thus enclosed in the hearts of the timbers, and the air having no access to the exterior of them to carry off the moisture by evaporation, internal decay is the necessary consequence. I have sometimes witnessed these parts of the frame of a ship in such a rotten state, as to have been justly compared by the workmen to a heap of manure. Secondly, those timbers in the midships that have been bored off with the outside planks, are not so affected, which I attribute to the circumstance of the holes admitting a current of air through them, the destructive juices being thereby carried off. Thirdly, it frequently happens, that the floor-timbers of an old ship are found, on breaking up, to be nearly as sound as they were when first put in. Their preservation seems to be owing to the effect of the salt water, which constantly laves over them, causing them to become, in a manner, pickled; or it may be, that the salt entering into the composition of the wood, the destructive effects of its natural juices are thereby prevented. Fourthly, the planks in the bottom, nearest to the timbers, take the infection first; and where the tree-nails are not close, the disease rapidly extends endways of the grain. Fifthly, those parts of the deck-planks that lie *upon* the beams are

those which are first infected with the rot, the cause of which is evident, as those parts that are *between* the beams are generally quite sound. Sixthly, in the beams of ships the decay usually commences in the internal parts, which is decidedly owing, in my opinion, to the erroneous method of preparing the timber, as before-mentioned; but when timber, so prepared, is used, I would recommend, as the best preventive of the rot, that a few holes be bored through the beam fore and aft, and, what would still add to the benefit, to bore another hole lengthways of the grain, to meet those which are bored crossways. But the best preventive, I am confident, would be the adoption of my mode of preparing the timber, viz., to saw it lengthways right through the heart, by which not only greater durability would be obtained, but great economy in the consumption of the timber."

Though, as we have before observed, volumes have been written on the subject of dry-rot, the causes of it are still, perhaps, as little understood as ever; and, as was stated by Mr. Bramley, of Leeds, in a paper read to the Society for the Encouragement of Arts, &c., "to bring the matter to the test by experiments, would require the observations of a long period, and in selected situations." "Wood used for the general purposes of man," he observes, "is cut down at different periods; and although it may be felled at the proper season, or when most free from sap or moisture, it is not always to be effected. Nay, even admitting it to have been cut down in the most favourable situation, it still abounds with such an extra proportion of moisture, as to require a regular exposure to the air prior to its being applied to use, if we wish to guard against that shrinking which always takes place where this precaution has not been taken. And although the fir-kind contains less of this watery portion, yet it assuredly possesses a considerable share; and it is in this species, he apprehends, that the evil, called *the dry-rot*, most generally occurs; as, from the facility of working the same, it is most generally applied to buildings. But, supposing it to be fir, or any other species, wood felled when abounding with any extra proportion of sap, and applied to use without the proper seasoning or exposure to a free current of air, until such extra moisture has had time to exhale, is most liable to the disease in question; and the cure, or principal prevention against it, would be the precaution of felling all wood only at the proper season, or when the sap is not in circulation. The next mode of prevention would be to use such wood only as has been for a considerable period exposed to the influence of a free current of air, or, where convenience will admit, to that of air heated to a moderate degree; such air extracting, with greater facility, the enclosed moisture, and in a more certain ratio than the irregularity of our atmosphere will allow under other circumstances."

This is not the place for examining into the comparative merits of the different processes which have been introduced for seasoning timber. The most noted of these are Kyan's, Burnett's, Payne's, and Bethell's, all of which have been described by their advocates as perfect preventives of dry-rot; it is sufficient to say, that they have all been found successful, and have also all failed. The best preventive of dry-rot, in our opinion, is to have the timber thoroughly dry before it is converted, and to let plenty of air get to it when the building is completed.

DUBBING, in bricklaying, is replacing and making good any decayed brickwork, when the wall is to be repointed.

DUN, or BURGH, the name of an ancient species of buildings, of a circular form, common in the Orkney and Shetland Islands, the Hebrides, and northern parts of Scotland. The latter term points out the founders, who at the same time bestowed on them their natal name of *borg*, "a defence or castle," a Suco-Gothic word; and the Highlanders universally apply to these places the Celtic name *dun*, signifying a hill defended by a tower, which plainly points out their use. They are confined to the countries once subject to the crown of Norway. With few exceptions, they are built within sight of the sea, and one or more within sight of the other; so that on a signal by fire, by flag, or by trumpet, they could give notice of approaching danger, and yield a mutual succour. In the Shetland and Orkney islands, they are most frequently called *wart* or *ward hills*, which shows that they were garrisoned. They had their wardmadher, or watchman, a sort of sentinel, who stood on the top, and challenged all who came in sight. The gackman was an officer of the same kind, who not only was on the watch against surprise, but was to give notice if he saw any ships in distress. He was allowed a large horn of generous liquor, which he had always by him, to keep up his spirits. Along the Orkney and Shetland shores, they almost form a chain; and by that means not only kept the natives in subjection, but were situated commodiously for covering the landing of their countrymen, who were perpetually roving on piratical expeditions. These towers were even made use of as state prisons; for we learn from Torfæus, that after Sueno had surprised Paul, count of Caithness, he carried him into Sutherland, and confined him there in a Norwegian tower. Out of our own kingdom, no buildings similar to these are to be found, except in Scandinavia. On the mountain Swalberg in Norway is one; the Stir-biskop, at Upsal in Sweden, is another; and Umseborg, in the same kingdom, is a third.

In these buildings, there is no appearance of an arch; the wall, which consists of the best flat stones the workmen could find, is well laid, is in thickness about 14 feet, and in some instances not more than 12 feet high; the structure of a dun is upon a circular plan, about 20 or 30 feet in diameter. The door of entrance is very low, and was shut up occasionally with a broad flat stone. In some instances, where the stones were not flat or well bedded, the wall is found propped up with heaps of stones, like buttresses, on the outside; so as to give the whole more the appearance of a mount, than of a building, as is particularly the case with one at Lothbeg, in the parish of Lothis. The most entire dun is that at Glenby, not far from Inverness, and described by Mr. Pennant, in his voyage to the Hebrides; from whose very curious and original account, the following particulars are extracted:—

"It is placed about two miles from the mouth of the valley. The more entire side is about thirty feet six inches in height, and was, some years ago, about ten feet higher. The whole structure appears to have been, on the outside, of a conical form; but on the inside, the surrounding wall is quite perpendicular, so that it must have been much thicker at the bottom than at the top. It enclosed a small circular area of thirty-three feet and a half in diameter; and was constructed merely of flat stones neatly placed one upon another, without any cement or mortar. At ten feet from the ground it was found to be seven feet four inches thick; and within this thickness were two surrounding galleries; one quite in the lower part of the tower, about six feet two inches high, and two feet five inches wide at the bottom; but made narrower at the top; and flagged and covered with great flat stones. And the other gallery was placed directly over this, having these flag-stones for its floor, and being only five feet six inches high, and only twenty inches wide at the bottom; but covered at top, in like manner, with other great flat stones.

"This upper gallery, in which a man could barely make his way, went quite round the tower, without any division or partition; but the lower gallery, underneath this, is parted off into separate spaces, by great flag-stones placed upright; which several spaces, or little cells, were in general accessible only by means of holes in the floor or gallery above; so that nothing can be more obvious, than that these cells were intended for the keeping and preserving of stores; whilst the upper gallery cannot but remind us somewhat of the little gallery within the wall of the round tower at Brunless.

"Besides these galleries, there were, on the inside of the circular wall, open to the circular enclosed apartment, four perpendicular rows of small cavities, or, as they have been described by others, four stages or nests of small square open holes, dividing the interior circular wall into four parts, and turning up from the lower part of the tower to the top; each little hole, or nest, in the row, divided from that beneath only by a sort of shelf, or flag-stone, and forming a little cupboard.

"The appearance of this sort of little cupboards, as well as that of the sections of galleries, is similar to those in this tower, as they are seen in the wall of another dun, in the same neighbourhood. And these square cavities seem obviously to have been intended to hold the drinking horns, and other utensils for banqueting in these rude dens."

DUODECIMALS, a term applied to an arithmetical method of ascertaining the number of square feet and square inches in a rectangular space, whose sides are given in feet and inches.

In this series of denominations (beginning with feet) every unit in the preceding denomination makes twelve in that which succeeds it: that is, every foot contains 12 inches, or firsts; every first, 12 seconds; and so on. There will be as many denominations in the product as in both factors taken together.

Feet are either marked with or without an *f;* inches are called *firsts* by the mark thus (′) being placed above; *seconds* by the mark thus (″) being placed above; *thirds* thus (‴), and so on. In multiplying any two single denominations together, the value of the product will be known by adding the indices of the two factors. Thus, suppose $\overset{\prime\prime}{7}$ to be multiplied by $\overset{\prime\prime\prime}{11}$, then the product is $\overset{\text{v}}{77}$, or 77 fifths, because adding the index ″ of the seven to the index ‴ of the eleven, produces v or fifths.

To multiply duodecimals together.—Write the multiplier under the multiplicand, so that the place of feet may stand under the last place of the multiplicand; begin with the right-hand denomination of the multiplier, and multiply it by every denomination of the multiplicand, throwing the twelves out of every product, and carrying as many units to the next; place the remainders, if any, under the multiplier, so that like parts in the product may be under like parts of the multiplicand; proceed with every successive figure of the multiplier, towards the left, in the same manner, always placing the first figure of the product under the multiplier; then the sum of the products will be the total.

Example 1.

Multiply 6..9′ by 3..6′

$$\begin{array}{lrl}
 & \overset{\text{ft.}}{6}..\overset{\prime}{9} & \\
 & 3..6 & \\
\hline
 & 3..4..6 & = 6..9 \times 6 \\
 & 20..3 & = 6..9 \times 3 \\
\hline
\text{Answer} & 23..7..6 &
\end{array}$$

Example 2.

Multiply 6..5′..4″ by 3..6′

$$\begin{array}{lrl}
 & \overset{\text{ft.}}{6}..\overset{\prime}{5}..\overset{\prime\prime}{4} & \\
 & 3..6 & \\
\hline
 & 3..2..8..0 & = \overset{\text{ft.}}{6}..\overset{\prime}{5}..\overset{\prime\prime}{4} \times 6 \\
 & 19..4..0 & = 6..5..4 \times 3 \\
\hline
\text{Answer} & 22..6..8..0 &
\end{array}$$

In the first example, there is only one place of duodecimals in each factor; there are, therefore, two places in the product.

In the second example, there are two places of duodecimals in the multiplicand, and one in the multiplier, which make together three; there are, therefore, three denominations in the product.

Example 3.

What is the product of $\overset{\text{ft}}{4}..\overset{\prime}{3}..\overset{\prime\prime}{2}..\overset{\prime\prime\prime}{8}..\overset{\text{iv}}{9}..\overset{\text{v}}{5}..\overset{\text{vi}}{3}$ by $\overset{\prime}{3}..\overset{\prime\prime}{0}..\overset{\prime\prime\prime}{5}..\overset{\text{iv}}{0}..\overset{\text{v}}{0}..\overset{\text{vi}}{6}..\overset{\text{vii}}{2}$

$$\begin{array}{r}
\overset{\text{ft}}{4}..\overset{\prime}{3}..\overset{\prime\prime}{2}..\overset{\prime\prime\prime}{8}..\overset{\text{iv}}{9}..\overset{\text{v}}{5}..\overset{\text{vi}}{3} \\
0..\ 3..0..5..0..0..\ 6..2 \\
\hline
8..6..5..5..6..10..6 \\
2..1..\ 7..4..4..8..7..\ 6 \\
1..9..4..1..7..\ 11..2..3 \\
1..0..9..8..2..4..3..\ 9 \\
\hline
1..0..11..5..6..8..2..\ 0..\ 1..1..2..2..4..6
\end{array}$$

In this example, because there are no feet in the multiplier, the place is supplied by the cipher. The multiplicand has six places of duodecimals, and the multiplier seven; there are, therefore, thirteen places of duodecimals in the product. The first place of figures is feet, and the succeeding are the duodecimal places; the product is one foot, no inches, eleven seconds, five thirds, &c. But, independently of the consideration of there being as many places of duodecimals in the product as in the multiplier and multiplicand, the method of placing the denominations of the factors gives the correct places of the product, since like parts of the product stand under like parts of the multiplicand; it also shows the affinity, not only between duodecimals, but between decimals and every series of denominations, of which the same number in any place makes one of the next towards the left hand. The consideration is also useful, in discovering readily what kind of product arises by multiplying any two single denominations together.

When the number of feet runs very high in each factor, it will be much better to reduce all the denominations in both into the lowest, then multiply the factors, so reduced, and divide by 12 as often as there are duodecimal places in the product.

Example 4.

Multiply $\overset{\text{ft}}{6}..\overset{\prime}{5}..\overset{\prime\prime}{4}$ by $\overset{\text{ft}}{3}..\overset{\prime}{6}$ as in Example 1.

$$\begin{array}{rlcr}
6 & 5..\overset{\prime\prime}{4} & \qquad & 3..\overset{\prime}{6} \\
12 & & & 12 \\
\cline{1-1}\cline{4-4}
77 & & & 42 \\
12 & & & \\
\cline{1-1}
928 & & & \\
42 & & & \\
\cline{1-1}
1856 & & & \\
3712 & & & \\
\cline{1-1}
12)38976 & & & \\
12)3248 & & & \\
12)270..8 & & & \\
\cline{1-1}
22..6..8 & \text{the same as before} & &
\end{array}$$

Example 5.

Multiply $\overset{ft}{3}..\acute{6}..\ddot{4}..6'''..\overset{iv}{5}$ by $\overset{ft}{0}..\acute{0}..5''..3'''$

$$\begin{array}{rr}
5''..3''' & \overset{ft}{3}..6'..4''..6'''..\overset{iv}{5} \\
12 & 12 \\
\hline
63 & 42 \\
 & 12 \\
\hline
 & 508 \\
 & 12 \\
\hline
 & 6102 \\
 & 12 \\
\hline
 & 73229 \\
 & 63 \\
\hline
 & 219687 \\
 & 439374 \\
\hline
 & 12)4613427 \\
\hline
 & 12)384452..3 \\
\hline
 & 12)32037..8 \\
\hline
 & 12)2669..9 \\
\hline
 & 12)222..5 \\
\hline
 & 12)18..6 \\
\hline
 & 12)1..6 \\
\hline
 & 0..1..6..6..5..9..8..3
\end{array}$$

Proofs by duodecimals.

$$\begin{array}{r}
\overset{ft}{3}..6'..4''..6'''..\overset{iv}{5} \\
0..0..5..3 \\
\hline
0..10..7..1..7..3 \\
1..5..7..10..8..1 \\
\hline
1..6..6..5..9..8..3
\end{array}$$

the product, the same as by duodecimals.

In this example, because there are seven places of duodecimals in the two factors, viz., four in the multiplicand, and three in the multiplier, the product 4613427 is divided seven times successively by 12.

There is another method of duodecimals, almost equally convenient. The rule is as follows: First.—Under the multiplicand, place the corresponding denominations of the multiplier.

Then multiply each denomination, from right to left, of the multiplicand, by each term of the multiplier successively from the left to the right, placing the first denomination of each row, or product, one place nearer to the right, and carrying one from every twelve in the product of any denomination, to that which succeeds it towards the left, up to the place of feet; then the sum of all the like products will be the total.

Example 6.

Multiply $\overset{ft}{10}..4'..5''$ by $\overset{ft}{7}..8'..6''$

$$\begin{array}{rl}
\overset{ft}{10}..\ 4'..\ 5'' & \text{Multiplicand.} \\
7..\ 8..\ 6 & \text{Multiplier.} \\
\hline
72..\ 6..11 & \\
6..10..11..4 & \\
5..\ 2..2..6 & \\
\hline
79..11..\ 0..6..6 &
\end{array}$$

Example 7.

Multiply $\overset{ft}{23}..4'..6''..7'''$ by $\overset{ft}{7}..8'..5''..10'''$

$$\begin{array}{r}
\overset{ft}{23}..4'..\ 6''..\ 7''' \\
7..8..\ 5..10 \\
\hline
163..7..10..\ 1 \\
15..7..\ 0..\ 4..8 \\
9..\ 8..10..8..11 \\
1..\ 9..\ 5..9..\ 5..10 \\
\hline
180..2..\ 4..10..2..4..10
\end{array}$$

Proof by the first method.

$$\begin{array}{r}
\overset{ft}{23}..4'..\ 6''..\ 7''' \qquad\qquad \\
7..8..\ 5..10 \\
\hline
1..\ 9..\ 5..9..\ 5..10 \\
9..\ 8..10..8..11 \quad \\
15..7..\ 0..\ 4..8 \qquad \\
163..7..10..\ 1 \qquad\quad \\
\hline
180..2..\ 4..10..2..\ 4..10
\end{array}$$

There is the same number of figures in each operation, but in the last the products are inverted. The first method, which is here used to prove the second, is similar to the common method of multiplication of integers, the first place of figures of every product being placed under the second denomination towards the left.

When feet and inches only are concerned, the reader is referred to the articles CROSS MULTIPLICATION, and PRACTICE.

DWANGS, a term used in Scotland, for the short pieces of timber employed in strutting a floor.

DWARF WALLS, low walls of less height than the story of a building. Sometimes the joists of a ground-floor rest upon dwarf walls; and the enclosures of courts are frequently formed by them with a railing of iron on their top: indeed, any low wall used as a fence, may be termed a dwarf wall.

DWELLING-HOUSE. *See* BUILDING and HOUSE.

DYE, the plain part of a pedestal, contained between the base and cornice, in the form of a square prism, approaching frequently to a cube or dye, whence the name originates.

The dye of a pedestal is generally placed in the same vertical plane with the vertical sides of the plinths of columns; there is, however, an instance in the dye of the pedestals of the columns of the Stoa, or Portico, at Athens, where the dye recedes within the vertical sides of the plinths of the bases. The practice of using pedestals under columns, is bad at the best; but in this instance their employment is still more ridiculous, being contrary to the rules of true taste and philosophy.

DYE, is also used for a cube of stone, placed under the feet of a statue and beneath its pedestal, to raise, and show it to more advantage.

DYE. *See* DADO.

DYNAMOMETER, (*measurer of power*), a term which has been applied to an instrument for measuring force or power. The Dynamometer has been used by engineers for ascertaining the tractive power required in drawing carriages

upon roads or vessels, upon canals, and also for measuring the relative force of men and other animals. These effects are usually manifested by the compression or distension of a strong spring, or by a steel-yard upon the principle of a bent lever balance; but in both these constructions the instrument is subject to great vibration, owing to the inequalities in the resistance and in the moving force, which render the indications very uncertain. A very ingenious application of the Dynamometer was made by Sir John Macneill, to the Road indicator, in experiments on the comparative condition of different descriptions of roads.

DYPTERON. *See* DIPTERON.

E.

EARS. *See* CROSETTES and ANCONES.

EAGLE, in architecture, a figure of that bird anciently used as an attribute of Jupiter, in the capitals and friezes of the columns of temples consecrated to that deity.

Also a lettern, or reading-desk, used in churches, from whence the lessons are read. It is so called from its form, which is that of an eagle with outspread wings, on which the book is laid, sometimes represented as trampling under foot a serpent. The material is generally brass, and the image is supported on a stem of similar material, pierced and otherwise enriched. *See* LETTERN.

EARTH-TABLE, the course of masonry or other work level with the ground.

EARTHEN FLOORS. *See* FLOORS.

EATING-ROOM. *See* DINING-ROOM.

EAVES, (from the Saxon,) the margin or edge of the roof of a house, which overhangs the walls, in order to throw off the water from the face of the masonry or brickwork.

EAVES LATH, or EAVES BOARD, an arris fillet, or thick feather-edged board, placed at the eaves of a roof, for raising the bottom of the first course of slates above the sloping plane of the side of the roof, so as that the next course may be properly bedded: that is, when the lower ends rest firmly upon those which form the eaves-course. It is sometimes also called *eaves catch*.

EBONY, a species of hard, heavy, and durable wood, which admits of a fine polish or gloss. The most usual colour is black, red, or green; but the best i sa jet black, free from veins and rind, very heavy, astringent, and of an acrid pungent taste. Ebony is wrought into toys, and is much used for mosaic and inlaid work.

ECATÆA, statues erected to the goddess Hecate, for whom the Athenians had a great veneration, believing her to be the overseer and protectress of their families.

ECBATANA, the capital of ancient Media, and the residence of the Median and Persian kings. It was situated in a plain, about twelve stadia from mount Orontes. Diodorus says it was 250 stadia in circuit. The walls were seven in number, built upon a circular plan, rising gradually above each other, by the height of each wall conforming in a great measure to the situation of the ground. In the book of *Judith*, we read that they were 60 cubits in height, and 50 in breadth; that the towers over the gates were 100 cubits in height, and the breadth of the foundation 60 cubits, and that the walls were built of hewn and polished stones, each stone being 6 cubits in length and 3 in breadth. The royal palace and treasury were within the inmost of the seven walls. Diodorus says, the timber of the palace was cedar or cypress; and various parts of it were cased with gold or silver. There are no monuments remaining of this superb palace, where the monarchs of Asia generally passed their summer; and it is rather to be lamented that a disagreement should exist among modern travellers, about the site on which this stately metropolis stood.

The site of Ecbatana has been a matter of dispute; but the dispute has arisen solely because those who have discussed the question, either did not know the evidence on which the question must be decided, or did not understand it. The route of commerce between the low country in the ancient Seleucia, and the modern Bagdad and the high table-land of Iran, is determined by the physical character of the country, and has continued the same from the earliest recorded history of those countries, to the present day. The places marked in the "Itinerary" of Isidore, as lying between Seleucia and Ecbatana, are the places indicated by modern travellers as lying on the route between Bagdad and Hamadan.

ECCENTRICITY, the distance between the foci of an ellipsis; it is otherwise called *ellipticity*.

ECCLESIASTICAL ARCHITECTURE. Under this title it is our intention to inquire into the nature of the places of worship employed by the early Christians, to consider the origin and progress of buildings devoted to this purpose, with a cursory glance at their history, and to describe generally their form, distribution, and structural arrangement.

Information on such subjects is to be sought for amongst the patristic writings, the early ecclesiastical historians, more especially Eusebius, and the early Christian writers generally. Collateral evidence corroborative of the testimony afforded from such sources, is to be found amongst cotemporary heathen authors in their occasional and incidental reference to such subjects. Evidence on this matter from all sources has been carefully collated, and much valuable information gained by the patient and learned research of Bingham, who has included it in his most elaborate work, the *Origines Ecclesiasticæ;* to which we shall have occasion frequently to refer in the following pages.

Of the forms of churches for the first three centuries, during the time of persecution, we know but little; and it is probable that during the very earliest period, when the Christian church was in a normal state, so to speak, whilst she numbered but few advocates, and they poor and of little influence, when "not many wise, not many noble were called;" it is probable, we repeat, that Christians had no fixed form or arrangement of parts in their places of public worship, but that a dwelling-house of some member or even a portion of such house, was set apart for the purpose. It is nearly certain that no structures were built for the especial purpose, during the first division of this period; for not only would they have attracted attention and suspicion, but would have been destroyed together with the worshippers: the earliest Christians were compelled to secrecy and obscurity, at least they did not bring themselves offensively or ostentatiously forwards into notice, although not shrinking from an open avowal of their faith when called upon for it; for be it remembered, they were to be "wise as serpents, and harmless as doves."

In the Sacred Writings, more especially in the "Acts of the Apostles," and in the epistles to the various churches, we not unfrequently meet with the word *church*, or εκκλησια,

which must in some cases undoubtedly apply to the edifice or room in which it was customary for the Christians to assemble; we know besides that it was a practice with the early Christians of the apostolic times to assemble together in some appointed place for the purpose of worship and devotion. It is evident from the accounts of the evangelists, that the eleven continued together after their Master's crucifixion, whether engaged in prayer and fasting, we cannot say; but they were certainly in one place when the women came and told them of the resurrection. In the evening of the same day, likewise, it is mentioned that they were assembled together in one place, and with closed doors, for fear of the Jews; and eight days afterwards, they were again together with closed doors. These would seem somewhat to invalidate the supposition of their being collected together for prayer, or at least public prayer, for it is mentioned that after the return of the apostles from Bethany, "they were continually in the Temple praising and blessing God." Again on the day of Pentecost, they were all together in one house, and, as it is noticed, with one accord, which expression would seem to express the existence of some object, reason, or purpose of their being together, and what more likely than for common prayer? yet they still attended the public services of the Temple, for it is related that after this, "Peter and John went up together into the Temple at the hour of prayer, being the ninth hour." After the incident which occurs at this time in the Temple, and when Peter and John were released from custody, they returned to their companions, who were assembled together —probably in the same place as before—and after relating the circumstances, it is told us that they prayed and "spake the word of God with boldness." Some time subsequent to these events, it is related of Paul and Barnabas, while at Antioch, that for a whole year they assembled themselves with the church, and taught much people. This was in all probability in a stated place set apart for the purpose. Still stronger is the probability with regard to the house of Mary, where Peter fled after his escape from prison, and where many Christians were gathered together praying; one might suppose that a room in her house had been given by Mary for the purpose of public worship. Lydia probably made a similar gift. But, not to multiply instances, we would particularly allude to a circumstance which occurred while Paul was staying at Troas; for it is related that "upon the first day of the week, when the disciples came together to break bread,"—in other words, to celebrate the eucharist,—"Paul preached unto them, ready to depart on the morrow, and continued his speech until midnight. And there were many lights in the upper chamber, where they were gathered together. Now there sat in a window, a certain young man named Eutychus, being fallen into a deep sleep; and as Paul was long preaching, he sunk down with sleep, and fell down from the third loft, and was taken up dead;" upon which Paul goes down to him, and restores him to life. This is probably the most minute description of the place, time, and mode of worship recorded in the Sacred Writings. It will not escape remark that the room in this instance is said to have been an upper room, and there is reason to believe that it was a practice amongst Christians, to use the upper room, or Hyperōon, for this purpose; it will be remembered that it was an upper room in which the Saviour celebrated the passover and instituted the eucharist, and it may possibly have been for some reason of this kind, rather than from the situation and nature of the place, that the upper room was adopted.

It has been maintained that the early Christians had no places set apart for public worship; but as Bingham combats this argument, it may be as well to let him speak for himself. His remarks are for the most part a summary of the inquiries of the learned Mede, who has treated this particular subject at considerable length:—

"A very singular paradox has been advanced by some learned man," says Bingham, "that for the three first centuries after Christ, (i. e.) before Constantine ascended the throne of the Roman empire, A.D. 306, when he established Christianity, and soon after abolished paganism, the Christians, owing to the cruel persecutions to which they were exposed by the pagans in these centuries, first under the tyrant Nero, A.D. 64; and next under the Roman emperor Domitian, A.D. 94, had no such places of worship as churches. This statement is grounded upon some mistaken passages of Origen, Minutius Felix, and Arnobius, who say that the Christians had no temples, which they take as a denial of their having any churches; which opinion, though advanced with some show of learning by Vedelius, Suicerus, and others, is altogether without foundation, contradicted by the authors which they allege, and by themselves in the arguments they produce. Dr. Mede has given us an elaborate disquisition on the subject, in confutation of this opinion, wherein he has collected the authorities of the ancients, which, for the three first ages, prove the existence of Christian churches.

"We shall briefly, for the sake of those who have not that learned author, give the substance of his proofs, and add some others of our own observation. In the first place, he shows that the ancient authors, St. Austin, St. Basil, St. Jerom, and St. Chrysostom, and those under the name of Sedulius, Œcumenius, Theophylact, in their comments on that passage of St. Paul, (1 Cor. xi. 22,) 'Have ye not houses to eat and drink in? or, despise ye the church of God?' all took the word church there, not for the assembly, but for an assembly-room, or place expressly set apart for sacred devotional purposes. Now the apostles, at stated seasons, were in the habit of meeting together for prayer, and supplication for the prosperity of Christianity, upon mount Zion, at Jerusalem, the Hyperōon, or upper room, so often mentioned in the Acts of the Apostles, (Acts i. 13,) and where they were gathered together when the Holy Ghost came upon them, (Acts ii.) and where our blessed Lord also celebrated his Last Supper, and where he appeared to his disciples on two successive sabbaths after his resurrection, to their great amazement, and at a time when the doors were close shut and barred, for fear of the Jews, (John xx. 19.) Here the seven deacons were elected and ordained, (Acts vi. 3,) and here the first council of the churches was held at Jerusalem, (Acts xv.) This place becoming holy and sacred by these meetings, was afterwards inclosed within a goodly edifice, called the church of mount Zion; and in the time of Cyril, bishop of Jerusalem, it was called the high church of the apostles.

"This was the οἰκος, or same house of assembly at Jerusalem, that is mentioned, (Acts ii. 46,) where the apostles met for the breaking of bread, when they had all things in common. Some think the word κατ οἰκω is not to be translated from house to house, as in our version, but in the house or room where the Christian assembly was used to meet together. The next argument is drawn from what Eusebius observes of the θεραπευται in Egypt, whether Essenes, or Christians, they had their σεμνεια, or places appropriated for divine worship, from the days of St. Mark, and that such places are to be understood in all such passages of St. Paul, as "Salute ye the churches" in such and such an house; that is, the congregation which meet in the houses of such pious Christians, who had generally some part of their dwelling, or upper rooms, or housetop, (see Acts x. 9,) remote from noise, set apart for the church to assemble in, or, like that of Lydia's, (Acts xvi. 15.) At Macedonia was such an

appropriated room, (see Acts xx.,) where St. Paul, on the first day of the week, preached to an immense multitude, and continued his discourse till midnight, when a young man, named Eutychus, sitting in the window where the lattice was open, being overcome by sleep, fell from the upper story, and was taken up dead, but whom St. Paul again restored to life. That there were devotional places, or oratories, set apart expressly for Christian worship in the first century, I think we have sufficient evidence; whether we call these places churches or not. The following century is, however, more clear, where they are called sometimes by the name of Cœnaculum; at others, by that which we have before mentioned, as Hyperoon. Thus we find Lucian, a pagan, or whoever was the author of the dialogue called Philopatris, about the time of Trajan, one of the pagan emperors, bringing in one Cretias, telling how the Christians carried him into a Hyperōon, the place of their assembly, with a design of making him a proselyte to their religion. He argues further, from the tradition of the church, derived from the ancient author of the Recognitians, under the name of Clemens Romanus, which says, that Theophilus, to whom St. Luke is supposed to have inscribed his Gospel at Antioch, where the name of Christians was first given to the followers of Christ, did convert his house into a church; and the like is reported of the house of Pudens, a Roman senator and martyr, in the Acta Pudentis, that it was turned into a church after his martyrdom. He concludes this first century with the testimony of Clemens Romanus, in his genuine epistle to the Corinthians, who says, that God has ordained well-appropriate places, where at appointed times and seasons he would be solemnly served, so that all things might be done religiously and orderly.

"In the second century, while the persecutions were still rife against the Christians, more cruel acts were passed under Trajan, A. D. 107, and Marcus Aurelius, A. D. 166, against them, by which it became necessary for them to act with firmness, and in compact. Thus Ignatius, in his epistle to the Magnesians, exhorts them to meet together in one place, which he calls τὸ ναὸν Θεȣ, the temple of God, and, in his epistle to the Philadelphians, he informs us, that at this time there was one altar in every church, and one apostolic bishop, or head, appointed with his presbytery and deacons. The present Greek copies, indeed, read it a little different from Dr. Mede, leaving out the word church, but the mentioning one altar is sufficient to intimate they had then a stated place for their ecclesiastical or Christian assembly. Tertullian, who lived in the following century, has clearly intimated that the Christians, at this time, had churches, when, complaining against those who followed the trade of idol-making, (for the Gentiles excused themselves, that they did not worship them,)—he says, 'the zeal of faith cannot declaim all the day long upon this point, bewailing that any Christians should come into the house of God from the shop of the enemy, and lift up their hands to God the Father, which were the mothers or makers of idols.' In another place he calls the church *Domus Columbæ*, the house of the dove, meaning either Christ, or his dove-like religion. And again, he expressly distinguishes between the baptistry and the church, which in those days were places separate from each other. In this age, Pius, bishop of Rome, wrote two short epistles to Justus, bishop of Vienne in Gaul; in the first of which is mentioned one Euprepia, a pious matron, who is said to have consigned the title of her house over to the church, in which was to be celebrated Divine offices of worship. And in the other epistle is named one Pastor, a presbyter, who is commended for erecting a titulus, that is, a small Christian church; Clemens Alexandrinus, towards the end of this century, also uses the name Ecclesia, for the place of the assembly, as well as the congregation; for, speaking of the church, he says, 'I call not now the place alone by this name, but the congregation of the elect people, the church;' and so, in his famous homily, *Quis dives Salvetur*, he brings in the Asian bishop, to whom St. John committed the young man to be trained up in the Christian discipline, complaining that the youth was become a villain and a robber, and, instead of following the church, had now betaken himself to the mountains, with a company like himself. By this it is plain, that, in his time, the word Ecclesia was taken for a church, or sacred place, as well as for the Christian assembly themselves, and that such a building as a church must have been known and understood. We have also the Scripture accounts of the seven Apocalyptic churches, in Asia Minor, to whom St. John the Divine, wrote from the isle of Patmos, where he was banished by the emperor Domitian, A. D. 96. These churches were Ephesus, Smyrna, Pergamos, Thyatira, Sardis, Philadelphia, and Laodicea, (Revelation ii. and iii.); some of whose ruins, as travellers inform us, now remain.

"In the third century, the testimonies are both more numerous and certain respecting the churches of the Apostolic Christians, though a succession of Roman emperors had passed edicts against them of a more severe and cruel nature, with the exception of that of Nero's. The persecuting emperors of this century were Septimius Severus, A.D. 203; Maximinus Thrax, A. D. 236; Decius, A. D. 250; Gallus, A. D. 253; Valerianus, A. D. 258; and lastly, Diocletian, A. D. 302.

"We have a testimony, in this age, of the existence of Christian churches, from a heathen author. Lampridius, in the life of Alexander Severus, reports, 'that there happening a dispute between the Christians and victuallers about a certain noted public place, each party challenging it as their own, the emperor's rescript determined it thus, in favour of the Christians: that it was better that God should be worshipped there after any manner, than that it should be given up to the victuallers.' About the middle of this period lived the famous Gregory of Neocæsarea, surnamed Thaumaturgus, who himself built several churches in Neocæsarea, and the adjacent parts of Pontus, as Gregory Nyssen reports in his life. St. Cyprian, about the same time, speaks of the place where the church assembled, under the name of Dominicum, the Lord's house; and, in another, opposes the church and the capitol—the altar of the Lord's house, and the altars of images and idol-gods, to one another; for, speaking against some that had lapsed, and, without due contrition, were for intruding themselves into the church again— 'If this were once permitted,' says he, 'what then remains but that the church should give way to the capitol, and the priests withdraw and take away the altar of the Lord with them, and let the images and idol-gods, with their altars, succeed, and take possession of the sanctuary, where the venerable bench of our clergy sit?' About this time, also, Dionysius, bishop of Alexandria, speaks of the churches as appropriate to the service of God.

"It appears further, from the rescript of Gallienus the emperor, recorded by Eusebius, where he restores the Christians their churches, under the name τοποι θρησηδισμοι, worshipping places; and from what has been noted before, out of the letter of Aurelian, which chides the senate for demurring about opening Sibylline books, as if they had been consulting, not in the capitol, but in a Christian church. As also that other rescript of his, in Eusebius, that the request of the council of Antioch ordered Paulus Samosatensis to be turned out of the house of the church. But the testimony of Eusebius goes further beyond all others; for

speaking of the peaceable times which the Christians enjoyed from the persecutions of Valerian to that of Diocletian, he observes, 'that the number of Christians so grew and multiplied in that *fifty years*, that their ancient churches were not large enough to receive them, and therefore they erected, from the foundations, more ample and spacious ones in every city.'

"The only objection against all this, made with any show of probability, is drawn from some of the ancient apologists—Origen, Minutius Felix, Arnobius, and Lactantius, who seem to say, 'that the Christians, in their time, had no temples or altars, nor ought to have any;' but, as Dr. Mede shows at large, this is only spoken against such temples, as the heathens pleaded for in the notion of encloistering the Deity by an idol, otherwise the very authors from whom the objection is drawn, must largely contradict themselves; for Arnobius owns they had their conventicula, houses of assembly, which he complains were barbarously destroyed in the last persecutions. And Lactantius says the same, giving them also the name of the temples of God, which Diocletian ordered to be demolished, at Bithynia. And Origen himself speaks of adorning the Christian churches and altars, in one of his Homilies upon Joshua. Lactantius, in another of his Institutions, speaks of one of the Christian conventicula in a town of Phrygia, which the heathen had burnt, with the whole assembly in it. And in his book *de Mortibus Persecutorum*, he gives a more particular account of the destruction of the churches throughout the heathen world; for he not only mentions the demolishing the stately churches of Nicomedia, in the kingdom of Bithynia, but intimates, that the same fate attended the churches over all the world; however it was, both Eusebius and Lactantius agreed in this one point, that there were churches before the last persecution.

"As a further proof of the existence of Christian churches in the middle of this century, we have a remarkable story told by Eusebius concerning the martyr Marinus, A.D. 259, in the time of Gallienus Marinus, who, being a candidate for a Roman office at Cæsarea, was informed against as a Christian, by an antagonist, who pleaded that he ought not to have the office, upon that score. The judge, upon examination finding it to be so, gives him three hours to consider whether he would quit his religion or his life. During this space, Theotecnus, bishop of Cæsarea, meets with him, and, taking him by the hand carries him to the church, and sets him by the holy table, then offers him a Bible and a sword, and bids him take his choice. He readily, without demur, lays his hand upon the Bible, whereupon the bishop thus bespake him: 'And here,' says he, 'adhere to God, and in his strength enjoy what thou hast chosen, and go in peace:' with this he immediately returned from the church to the judge, makes his confession, receives his sentence, and dies a martyr.

"Optatus takes notice of forty churches in Rome before the last persecution, which, being taken from the Christians, were afterwards restored to them by order of Maxentius, as St. Austin has more than once informed us. We have also read of some Christian churches in Africa, that were demolished in this persecution; as at Zama and Furni, noticed in the Gesta Purgationis of Cecilian and Felix. Others were taken away; and, in the mean time, till they were restored again, both councils and church-assemblies were held in private houses, as Optatus observes of the council of Cita. And St. Austin after him says, 'It was not to be wondered at, that a few bishops should hold a council in a private house, in the heat of persecution, when the martyrs made no scruple, in the like case, to be baptized in prison, and Christians meet in prison to celebrate the sacrament with the martyrs, as well as in secluded places.' But not to multiply instances of this nature, the very tenor of the imperial edicts, which raised the last persecution, is undeniable evidence, that the Christians, in all parts of the world, had their public churches, to which they resorted so long as they had opportunities to frequent them; for Eusebius says, 'the edicts of the emperors of Rome were sent to all the Roman provinces, even to Britain, commanding the churches of the Christians to be levelled with the ground, and the Bibles to be given up and burnt.' This was the last persecution, when Diocletian boasted that he had annihilated Christianity, and proclaimed the extirpation by exulting inscriptions—*Nomine Christianorum deleto qui templa evertebant;* and, *Superstitione Christi ubique deleta.* But the flame was not extinguished; it was again to break forth, for the mouth of the Lord had spoken it. Diocletian had now become hateful; soon after which he abdicated the throne, and Constantine the Great assumes the imperial sway of the Roman empire."

To these remarks we would add some further ones of Mede, and likewise give, at length, some passages referring to this subject, drawn from the writings of the early fathers who were living during the period we are speaking of.

Basil, speaking of the passage before alluded to, of *Have ye not houses to eat and to drink in?* &c., says, that we ought not to dishonour sacred places or things by the mixture of things of common use; and in answer to the question as to whether the Eucharist may be celebrated in a common house says, that as the word doth not allow that any common vessel or utensil shall be brought into places that are sacred, so likewise doth it forbid that the holy mysteries should be celebrated in a common house; for neither would the Old Testament permit any such thing to be done, nor our Lord, who said, "There is here one greater than the temple;" nor the apostle, saying, "Have ye not houses to eat and to drink in," &c. Whence we may learn, that we ought not to take our common supper in the church, nor should we dishonour the Lord's supper by eating it in a private house. But if one be necessitated to communicate in private, let them choose out the most clean and decent room for such a purpose, and withal see that he do it in the fittest and most seasonable time. St. Chrysostom says, on the same subject, "Behold a further change, that not the poor only, but also the church itself is injured. For, as hereby thou makest the Lord's supper a private supper, so thou dealest no better with the place, in that thou usest the church as a private and ordinary house." So again, Theodoret, "If ye come together to feast it, do this in your own houses, for to do thus in the church is a manifest contempt, a plain dishonour done to the church. For how can it but seem a thing wholly indecorous and absurd for you to fare deliciously in the temple of God, where the Lord himself is present, who hath prepared for us a common table, when at the same time those Christians that are poor are hungry, and out of countenance by reason of their poverty?" The author of the commentaries upon the epistles, alluding to the same text, says, "Ye despise the church of God, making it a place for common feasts and banquetings," and in the same track follow Theophylact and Œcumenius.

With regard to the nature of the earliest churches, and more especially to the Hyperōon, Mede says, "For the first it is not to be imagined they were such goodly and stately structures as the church had after the empire became Christian, and we now, by God's blessing, enjoy; but such as the state and condition of the times would permit, at the first some capable and convenient room within the walls or dwelling of some pious disciple, dedicated by the religious bounty of the owner to the use of the church, and that usually an Ἀνώγεον, or Ὑπερωον, an upper room, such as the Latins call *Cœnaculum*.

being, according to their manner of building, as the most large and capacious of any other, so likewise the most retired and freest from disturbance, and next to heaven, as having no other room above it. For such uppermost places we find they were wont then to make choice of, even for private devotions, as may be gathered from what we read of St. Peter, (Acts x. 9,) that he went up to the housetop to pray; for so δῶμα signifies *ex usu Hellenistarum*, and is accordingly here rendered by the vulgar Latin, *in superiora*.

"Such an Hyperöon as we speak of, was that remembered by the name of *Cœnaculum Sion*, where, after our Saviour was ascended, the apostles and disciples assembled together daily in prayer and supplication, and where, being thus assembled, the Holy Ghost came down upon them in cloven tongues of fire at the feast of Pentecost. Concerning which there hath been a tradition in the church, that this was the same room wherein our blessed Saviour, the night before his passion, celebrated the Passover with his disciples, and instituted the mystical Supper of his Body and Blood for the sacred rite of the gospel; the same place where, on the day of his resurrection, he came and stood in the midst of his disciples, the doors being shut, and, having showed them his hands and his feet, said '*Peace be unto you*,' &c; the place where, eight days, or the Sunday after, he appeared in the same manner again unto them, being together, to satisfy the incredulity of Thomas, who the first time was not with the rest; the place where James the brother of our Lord was created by the apostles, bishop of Jerusalem; the place where the seven deacons were elected and ordained; the place where the apostles and elders of the church at Jerusalem held that council, and pattern of all councils, for decision of that question—whether the Gentiles which believed were to be circumcised or not; and for certain, the place of this *Cœnaculum* was afterwards enclosed with a goodly church, known by the name of the church of Sion, upon the top of which it stood; insomuch that St. Jerome, in his *Epitaphio Paulæ*, made bold to apply that of the Psalm to it, 'Her foundations are upon the holy hills; the Lord loveth the gates of Sion more than all the dwellings of Jacob.' How soon this erection was made, I know not; but I believe it was much more ancient than those other churches erected in other places of that city by Constantine and his mother, because neither Eusebius, Socrates, Theodoret, nor Sozomen, make any mention of the foundation thereof, as they do of the rest. It is called by S. Cyril, who was bishop of the place, *the upper church of the apostles*; and says he, 'The Holy Ghost descended upon the apostles in the likeness of fiery tongues, here in Jerusalem, *in the upper church of the apostles*.'

"If this tradition be true, it should seem by it that this *Cœnaculum*, from the time our blessed Saviour first hallowed it by the celebration of his mystical Supper, was thenceforth devoted to be a place of prayer and holy assemblies. This is the more easy to be believed, if the house were the possession of some disciple at least, if not kindred also to our Saviour according to the flesh, which both reason persuades, and tradition likewise confirmeth it to have been.

"And if this were so, why may not I think that this *Cœnaculum Sion*, or upper room of Sion, was that οικος whereof we read, concerning the first Christian society at Jerusalem, that 'they continued daily in the Temple, and, breaking bread (κατ' οικον) in the house, ate their meat with gladness and singleness of heart?' the meaning being, that when they had performed their devotions daily in the temple at the accustomed times of prayer there, they used to resort immediately to the *Cœnaculum*, and there having celebrated the mystical banquet of the Holy Eucharist, afterwards took their ordinary and necessary repast with gladness and singleness of heart. For so κατ' οικον may be rendered; for ἐν οικω, and not *domatim* or *per domos*, *house by house*, as we translate it, and so both the Syriac and Arabic render it, and the New Testament elsewhere uses it."

It would seem from this last passage, that Mede sees no difficulty in reconciling the attendance of the apostles on the public service of the Jewish Temple, with the supposition that they likewise celebrated a common worship in their own chapels or consecrated places; and if we look into the matter, this double service will not appear extraordinary, for as yet they adhered to their Master's practice of worshipping at the Temple, while at the same time there were many peculiar and distinctive services in their new religion, which they could not perform in the Temple. For instance, the celebration of the Holy Eucharist was an essential no less than a peculiar rite, which they would not have been allowed, even supposing them willing, to have celebrated in the Temple; they were necessitated therefore to fulfil this command in their own places of worship. This seems to have formed a continuation and completion of the Temple service.

"Such as these, I suppose," continues Mede, "were the places at first set apart for holy meetings, much like to our private chapels now in great men's houses, though not for so general a use.

"In process of time, as the multitude of believers increased, some wealthy and devout Christian gave his whole house or mansion, either while he lived, if he could spare it, or bequeathed it at his death, unto the saints, to be set apart and accommodated for sacred assemblies and religious uses.

"At length, as the multitude of believers still more increased, and the Church grew more able, they built them structures of purpose, partly in the cemeteries of martyrs, partly in other public places; even as the Jews—whose religion was no more the empire's than theirs—had, nevertheless, their synagogues in all cities and places where they lived among the Gentiles."

The following quotations from writers of the period will give some insight into the general use and nature of distinct places of worship in their days. In the second century, Ignatius speaking to the Magnesians, says, in the passage alluded to above, "All of you meet together for prayer in one place, let there be one common prayer, one mind, one hope in love, in the immaculate faith in Jesus Christ, than which nothing is better. All of you as one man run together to the temple of God, as to one altar, to one Jesus Christ, the High Priest of the unbegotten God."

In the third century Hippolytus, describing the state of the world at the coming of antichrist, says, "the temples of God shall be as common and ordinary houses; churches shall be utterly demolished everywhere; the Scriptures shall be despised:" thus showing the esteem in which churches were then held.

Gregory of Neocæsarea, surnamed Thaumaturgus, who lived in the middle of the third century, describing the five degrees or admission of penitents according to the discipline of his time, says, 1st. *Weeping* (the first degree of penance) was without the porch of the oratory, where the mournful sinners stood, and begged of all the faithful as they went in to pray for them. 2d. *Hearing* (the second degree) was within the Porch, in the place called *Narthex*, the place where these penitent sinners (being now under the *ferula* or censure of the church) might stand near to the catechumens, and hear the Scripture read and expounded, but were to go out before them. 3d. *Prostration or lying along on the Church-pavement*. These *prostrate* ones were admitted some what further into the church, and went out with the catechumens. 4th. *Standing or staying with the People or*

Congregation. These *Consistentes* did not go out with the *Catechumens*, but after they and the other penitents had left, remained, and joined in prayer with the faithful. 5th. *Participation o the Sacraments.*" This is a somewhat remarkable passage, to which we shall have occasion again to refer.

In the rescript of Galienus the churches of the Christians are mentioned as Τοποι Θρησκευσιμοι or Places of Worship. Gregory Nyssen, speaking of the success of Gregory of Neocæsarea, relates, "How that, becoming all things to all men, he had in a short time gained a great number of converts through the assistance of the Divine Spirit, and that hereupon he had a strong desire to set upon the building of a temple or place for sacred assemblies; wherein he was the more encouraged by the general forwardness he observed among the converts to contribute both their moneys and their best assistance to so good a work. This is that temple which is to be seen even at this day." Eusebius, speaking of the long peace which the Church enjoyed before the persecution of Diocletian, says, "How shall any one be able to express those infinite multitudes of Christians assembling in every city, those famous meetings of theirs in their oratories or churches? and therefore they, not being content with those smaller churches which before they had, (those their ancient edifices not being large enough to receive so great a number,) took care to erect from the very foundation fairer and more spacious ones in every city."

Soon after this dreadful persecution Constantine succeeded to the government, and having been fully convinced of the truth of the Christian faith, with hearty and unremitting zeal set about its establishment, nor to any thing did he give more constant attention than to the erection and adornment of churches. Before, however, entering upon a description and examination of these edifices, it may be as well to say a few words respecting a subject which has not been agreed upon amongst the learned; it is this, whether the early Christians made use of heathen temples for the performance of their public services. Bingham enters into the subject at some length, from whom we quote the following:—

"At first, when the reformation from heathenism was in its infancy, no idol-temples were made use of as churches, but were either permitted to the heathen for some time, or else shut up or demolished. Till the twenty-fifth year of Constantine, A.D. 333, the temples were in a great measure tolerated, but in that year he published his laws commanding temples, altars, and images to be destroyed, which laws are sometimes referred to in the Theodosian code. And pursuant to these laws, a great many temples were defaced in all parts of the world, and their revenues confiscated, as appears not only from the Christian writers, St. Jerome and Eusebius, and others, but also from the complaints of the heathen writers, Eunapius, Libanius, and Julian. In some of the following reigns also the same method was taken to shut up or to deface the temples, as is evident from the account which Ruffin gives of the general destruction of them in Egypt by the order of Valentinian. But in the next reign, in the time of Theodosius, another method was taken with some of them. For as Gothofred observes, out of the Chronicon Alexandrinum:—'Theodosius turned the famous temple of Heliopolis, called Balanium, into a Christian church, (εποιησεαυτο εκκλησιαν χριστιανων.) And about the same time Socrates tells us, 'That when Valens had banished the two Macarii, the heads of the Egyptian monks, into a pagan island, they converted all the inhabitants, and turned their temple into the form of a church.' The like was done by the famous temple of the Dea Celestis at Carthage, by Aurelius, the bishop, in the time of Honorius, A.D. 399, which the author of the book, *de prædictionibus*, under the name of Prosper, tells, with this remarkable circumstance, 'that it had been dedicated before by one Aurelius, a heathen high priest, with this inscription, *Aurelius pontifex dedicavit*, which our author says was left in the frontispiece, to be read by all the people, because, by God's providence, it was fulfilled again in Aurelius the bishop, for whom it served as well as the former Aurelius, when he had once dedicated it to the use and service of the Christian religion, and set his chair in the place of the goddess. Not long after this, Honorius published two laws in the Western empire, forbidding the destruction of any more temples in cities, because they might serve for ornament, or public use, being once purged of all unlawful furniture—idols and altars, which he ordered to be destroyed wherever they were found.

"These laws, as Gothofred rightly observes, seem to have been published at the instance of the African fathers, who, as appears from one of the canons of the African code, petitioned the emperor, that such temples as were in the country only, and private places not serving for any ornament, might be destroyed. Arcadius published such another law for the Eastern empire, which relates only to the destruction of temples in country-places, and not in cities, where now there was no such danger of superstition, since they might be converted to a better use. And upon this ground the author, under the name of Prosper, commends Honorius for his piety and devotion, because he gave all the temples, with their adjacent places, to the church, only requiring the idols to be destroyed. 'Tis true, indeed, after this we find a law of Theodosius Junior commanding all temples to be destroyed; but, as Gothofred seems rightly to interpret it, "the word *destroying*, in that law, is to be understood only of despoiling them of their superstition, because it follows in the same law, that they were to be expiated by placing the sign of the cross upon them, which was a token of their being turned into churches. And his observation may be confirmed further from what Evagrius reports of Theodosius—that he turned the Tycæum, or Temple of Fortune at Antioch, into a church called by the name of Ignatius. The like was done by a great temple at Tanis in Egypt, as Valesius has observed out of the Itinerary of Antonius the martyr.

"Cluver also, in his description of Italy, takes notice of a place in the Jerusalem Itinerary, called Sacraria, betwixt Fulginum and Spoletum, near the head of the river Clitumnus, which he thinks was no other than the temple of Jupiter Clitumnus, though another learned antiquary makes it somewhat doubtful as to the present church now standing there. However, we have seen instances enough of this practice, and Bede tells us, that 'Gregory the Great gave Austin the monk instructions of the same nature about the temples here among the Saxons in Britain,—that if they were well built they should not be destroyed, but only be converted from the worship of devils to the service of the true God.' And so he observes it was done at Rome, where, not long after, Boniface the Fourth turned the heathen temple, called the Pantheon, into the church of All Saints, in the time of the emperor Phocas. Sometimes the temples were pulled down, and the materials were given to the church, out of which new edifices were erected for the service of religion, as Sozomen and Ruffin particularly observe of the temples of Bacchus and Serapis at Alexandria. I have already shown out of Antonius, that the Roman halls or basilicæ were likewise turned into churches. The like is reported of some Jewish synagogues by the author of the Chronicon Alexandrinum, who takes notice particularly of a synagogue of the Samaritans, in a place called Gargarida, which Zeno the emperor converted into a large Christian church.

"And though it is not agreed by learned men whether the

temples said to be built by Hadrian were intended for the worship of himself, or the worship of Christ; for Casaubon and Pagi think he designed them for himself, whilst Huetius defends Lampridius, his relation, who says, "He designed them for the honour of Christ;" yet it is certain, that after they had been used to other purposes, they were at last, some of them, turned into Christian churches: for Epiphanius says, 'There was a great temple at Tiberias, called the Hadrianum, which the Jews made use of for a bath; but Josephus Comes, the converted Jew, in the time of Constantine, turned it into a church.' And the like was done by another of them by Athanasius at Alexandria, having before been the hall or place of Licinius, as the same Epiphanius informs us. So that now, partly by the munificence of the emperors, and partly by their orders for converting heathen temples into churches, and partly by the great zeal and liberality of private Christians in times of peace, churches became another thing from what they were in former ages, that is, more noble and stately edifices, more rich and beautiful."

Thus far Bingham, who seems to conclude from the above quotations of the early writers, that to convert heathen temples into Christian churches was not an uncommon practice: a writer, however, in the Quarterly Review, in a critique on the publications of Knight and Bunsen, on Ecclesiastical Antiquities, arrives at a very different conclusion; and as he has evidently given more than ordinary attention to the subject, it may not be amiss to refer to his remarks, in this place:—

"The antipathy," says he, "borne by the early Christians to the fine arts, debased by the pollutions of heathen idolatry, can neither be denied nor concealed; and the same causes which prevented the cultivation of the arts, ensured the degradation and subversion of their proudest and most splendid monuments. Excluding for the present the consideration of other agencies, the first paragraph in the rise of Christian architecture, must narrate the fall of the structures devoted to the superstition, which it was the end of the gospel to obliterate and destroy.

"The heathen temples were doomed to inevitable ruin. Laws had been promulgated by Theodosius for their preservation; conducive to the decoration of the city, they might be perhaps rendered useful for the purposes of civil society. Some may have been thus respited, though not rescued, until the decayed remains crumbled to the ground; they were never respected or honoured by public opinion, and could rarely be adapted to the objects pointed out by the imperial law, without such alterations as in most cases amounted to destruction. Others were accidentally preserved in desolate or secluded situations, in the forest or the marsh, or the mountain-glen, or on the shore, whence the inhabitants have been extirpated, or chased away. Such are the columns of Pæstum: the heavens are yet as bright as when the garlands hung down from the ruined architrave; the sea as azure as when the waves were ploughed by the painted prows; the crushed herbs beneath your feet, still send up their rich perfume. To the senses, the works of art are still as noble, the works of nature as sweet and gay; but the whole scene mourns under the curse inflicted upon scoffing, lascivious, corrupted Hellas. Language, people, race—their very name has disappeared. The wasting pestilence still hovers, and will ever hover, marking the vengeance which has fallen on the deserted shore.

"Few temples were ever adapted for the purposes of Christian worship; fewest of all in the capital of the Christian world. 'Of the Christian hierarchy,' says Gibbon, 'the bishops of Rome were commonly the most prudent and the least fanatic; nor can any positive charge be opposed to the meritorious act of saving and converting the majestic structure of the Pantheon.' In casting the account of the merits and demerits of the Christian hierarchy, such a pontiff as Gregory the Great would have been ill inclined to accept the encomium. In the *gergo* of Gibbon, 'fanaticism' is piety, and 'prudence' unbelief. The 'meritorious act, thankful as we may be for the result, was a single item, by no means influencing the general balance of praise or dispraise; it was the solitary performance of Boniface IV.; it was an act from which no consequences resulted. With the exception of the Pantheon, we fail to detect any real example in Rome, of a temple which can be said to owe its *preservation*, in the *proper sense* of the term, to the Christian clergy. They had no thought of the kind—they took no pleasure in such antiquities. They sought no credit for such care. Antiquaries, with eager zeal, have collected about ten examples in which this preservation is asserted. Even in the cases which are least dubious, no further merit can be claimed for the hierarchy than the accidental preservation of a portico, a cella, or a wall, an encumbrance which it was troublesome to remove—a fragment which saved some expense, built up, concealed, marred, or deformed by the new erection to which it was unwillingly conjoined.

"It could not be otherwise. In the early Christians, any participation in our modern worship of heathen art, would have been false and unnatural. All the opinions, all the habits, all the feelings, all the conscience, of the early Christians strove against the preservation of the memorials of heathenism. Neither beauty nor convenience, if they had possessed the latter requisite, would, save in some few special cases, like that of the Pantheon, plead for the preservation of the relics of classical antiquity. They considered the idols as accursed. No object which had in anywise been connected with the worship of idols, or could be supposed to have been employed in their service, was to be used without exorcism. Thus, in the ritual of the church of Durham, there is a form of prayer for hallowing the vase found in the Roman encampment, which could not be employed for any Christian use until subjected to such purification. Nor was this belief confined to the rude Northumbrian peasant, or to a barbarous age. Let us place ourselves before the portal of St. Peter's, fresh from the workmen's hands. Four months have been employed in removing the huge obelisk of Sesostris from the ruins of Nero's Circus to the front of the great Basilica. Eight hundred workmen, toiling at creaking winch and groaning capstan, heave up the mass; whilst the breathless crowd watch the slow rising of the gigantic beam. It stops; when the one cry, '*aqua alle funi*,' which subjects the individual who suggests the happy expedient, to the pain of death, enables the maestro to complete his task; amidst the thunder of the cannon, the 'guglia' stands firm and erect upon its basement. But is the work complete? No: the trophy of the victory of Christianity over heathenism cannot yet be received as such, until all connection with its former slavery to the fiend has been destroyed. In solemn procession, the supreme pontiff exorcises the magnificent work, so long dedicated to the foul superstition of Misraim, and devotes it to the honour of the Cross, performing the rites which were deemed to expel the evil spirit. Those who may not share in the belief which dictated these ceremonies, must, nevertheless, respect the sentiments contained in the simple majestic language, commemorating the consecration of the spoils of heathenism to the service of the Cross. 'Ecce Crux Domini—Christus vincit—Christus regnat—Christus imperat—Christus ab omni malo plebem suam defendat—Vicit Leo de tribu Juda.'

"Thus did Pope Sixtus record his triumph. Yet there

was a greater triumph felt by the zeal which taught the early Christians to glory in casting down the altars and the high places devoted to sin; deeming—we will not presume to judge whether rightly or wrongly—that such a testimony to the truth was imperatively enjoined upon them. By their deeds they contemned the temporizing policy of the emperors. They sought the actual and visible victory of literally erecting the temple of the Lord upon the ruins of the habitation of the demon. The statues were broken, to be buried in the foundations; hence few sculptures have ever been found at Rome, which did not, like the Venus of the Medici, show by their defacement and fractures, the aversion of which they had been the objects. Amongst the great congregation of the faithful, the distaste, the horrors excited by paganism—its structures, monuments, glories, charms—were unconquerable and paramount. Idols might have been removed, and the building consecrated by the rites, which, according to the primitive belief, would drive away the demon; yet no lustration could entirely heal the leprosy of the walls. The language of the Virgin Martyr was echoed in every heart:—

> 'Your gods, your temples, brothel-houses rather;
> Or wicked actions of the worst of men,
> Pursued and practised. Your religious rites!
> Oh! call them rather juggling mysteries,
> The baits and nets of hell. . . . . . .
> Your Venus whom you worship, was a harlot—
> Flora, the foundress of the public stews,
> And has for that her sacrifice.
> Your Jupiter, a loose adulterer,
> Incestuous with his sister. Read but those
> That have canonized them. You will find them worse
> Than in chaste language I can speak them to you.'

"Whatever had been touched by paganism, seemed, and can we say unjustly? to be reeking with impurity."

On this subject we incline towards the opinions of the reviewer, notwithstanding the evidence adduced by Bingham; at the same time we do not mean to deny the occasional application of pagan temples to Christian uses under peculiar circumstances, as in the case of Austin and the Saxons at a later date, yet we do think the instances of such application were comparatively few, and formed the exception rather than the rule. For not only were the feelings of the early Christians enlisted against every thing connected with the worship of the heathen deities,—or devils, as St. Paul calls them,—but the form also of pagan temples was totally unsuitable for churches. Temples were little more than cells for the reception of the idol and priests, the people stood outside. The services of the Christian church required a very different arrangement; here you required accommodation for worshippers within the walls, as the very name εκκλησια, *assembly*, implies; there is here a communion or organized congregation. Christians came together not merely to behold as it were a spectacle, but to pray together, and to hear the Gospel read to them. "The Christian temple," says Professor Willis, "was a heathen temple turned inside out;" in the heathen temples the colonnade was outside, in the Christian church it was necessary to transpose it to the inside, to obtain greater internal space, as we see was the case in their later structures. Taking all this into consideration, we think there is some reason to decide that the examples of the adaptation of temples to the purpose of Christian worship, formed but exceptions. The very term *temple* was never used by the earlier writers, when speaking of the *church;* the terms were distinctive of the religion to which they belonged, the former when used, implying always heathen temples. The term employed in contra-distinction to this is εκκλησια, which, from being the name of the assembly, soon came to be applied to the place in which they met; this word is very common. Another appellation is κυριακον, *Dominicum, or Domus Dei*, which is met with in Eusebius and two or three councils; *Domus Columbæ* used by Tertullian, is a similar term. Other terms found in Eusebius, Socrates, Sozomen, and others, are προσευκτηρια and οἰκοι ευτηριοι; but one very frequent in the writers of the fourth and fifth centuries, though scarcely seen before, is Basilicæ. The word *temple* was seldom or never used in this sense during the first three centuries.

The earliest descriptions of early churches, now extant, are to be found in the writings of Eusebius, who gives somewhat lengthened accounts of the Holy Sepulchre at Jerusalem, and of the church of Paulinus at Tyre, which we proceed to notice. The descriptions are not very lucid; they show us how richly churches were adorned, and throw some little light upon their structure and arrangement, although the account is in many places confused; still it gives us some idea of the buildings, and, by comparison of this with other accounts, and with the remains of what are supposed to be earlier churches, we are enabled to decide pretty nearly their original form and distribution. He commences with a description of the Holy Sepulchre.

The Empress Helena, after a long search, succeeds in discovering the place of the Holy Sepulchre; which had been covered over by the pagans, and polluted by their rites, the place having been dedicated by them to Venus, a statue of which goddess was erected over the Sepulchre. Constantine having destroyed all the remains of heathenism, and having had the place purified from such abominations, proceeds to consider the erection of a suitable church upon the spot, and sends directions to Macarius, bishop of Jerusalem, upon the subject, a portion of which, as given by Eusebius, we transfer to these pages.

"Moreover, I would persuade you to that which is clear and evident, namely, that we ought to take especial care that this place, which we have purified and cleansed from superstitious idols, and which God and good men, from primitive times accounted sacred and holy, and which was afterwards so esteemed for the attestation and confirmation it gave to our belief in Christ's passion, should be honoured by erecting a church thereat. It is meet therefore that your wisdom should so dispose of this work, and prudently provide all things necessary thereto, that the beauty of the temple may excel all other churches, and the several parts of it may exceed the chief churches in other cities. Know therefore that we commit the care of erecting, building, and curiously adorning the walls thereof, to our friend Dracilianus and the president of your province. For out of our gracious bounty we have commanded them that they should have recourse to your wisdom to know what artificers and workmen shall be necessary to the building thereof, and accordingly shall straightway provide them, and send them thither. And when you have cast and contrived what marble pillars, or other marble works, will be necessary, either to adorn it, or make it more durable, look that you certify us by your letters, that when we understand what shall be necessary, we may provide accordingly. For this, which is the most special place of all the world, ought to be adorned with all kinds of work of cost and curiosity.

"I would have you certify me whether the roof of the sanctuary should be arched, or built in some other form; but if it be built archwise, it may be conveniently gilded. It remains therefore that your holiness should speedily signify unto those whom we have appointed to be overseers of the work, both what artificers and labourers will be necessary and what charge it will require; and also to certify us not

only concerning the pillars and other marble work, but also concerning the wood-work of the roof, if you think fit that it should be built in that form."

Then follows a glowing description of the building when completed, from which we extract the following:—

"First of all, then, he adorned the sacred cave itself, as the chief part of the whole work, and the hallowed monument of which the angel radiant with light had once declared to all that regeneration which was first manifested in the Saviour's person. This monument, therefore, first of all, as the chief part of the whole, the emperor's zealous magnificence beautified with rare columns, and properly enriched with the most splendid decorations of every kind. The next object of his attention was a space of ground of great extent, and open to the pure air of heaven. This he adorned with a pavement of finely-polished stone, and enclosed it on three sides with porticos of great length. For at the side opposite the sepulchre, which was the eastern side, the church itself was erected, a noble work rising to a vast height, and of great extent both in length and breadth. The interior of this structure was floored with marble slabs of various colours, whilst the external surface of the walls, which shone with polished stones exactly fitted together, exhibited a degree of splendour in no respect inferior to that of marble. With regard to the roof, it was covered on the outside with lead, as a protection against the rains of winter. But the inner part of the roof, which was finished with sculptured fretwork, extended in a series of connected compartments, like a vast sea, over the whole church; and being overlaid throughout with the purest gold, caused the entire building to glitter as it were with rays of light.

"Besides this, were two porticos on each side, with upper and lower ranges of pillars corresponding in length with the church itself, and these also had their roofs ornamented with gold. Of these porticos, those which were exterior to the church were supported by columns of immense size, while those within these rested on piers of stone beautifully adorned on the surface. Three gates placed exactly east were intended to receive those who entered the church.

"Opposite these gates, the crowning part of all was the hemisphere, which rose to the very summit of the church. This was encircled by twelve columns, (according to the number of the apostles of our Saviour,) having their capitals embellished with silver bowls of great size, which the emperor himself presented as a splendid offering to his God.

"In the next place he enclosed the atrium, which occupied the space leading to the entrances in front of the church. This comprehended first the court, then the porticos on each side, and lastly the gates of the court. After these, in the midst of the open market-place, the entrance-gates of the whole work which were of exquisite workmanship, afforded to passers-by, on the outside, a view of the interior, which could not fail to inspire astonishment.

"This temple, then, the emperor erected as a conspicuous monument of the Saviour's resurrection, and embellished it throughout on an imperial scale of magnificence. He further enriched it with numberless offerings of inexpressible beauty, consisting of gold, silver, and precious stones in various forms; the skilful and elaborate arrangement of which, in regard to their magnitude, number, and variety, we have not leisure at present to describe particularly."

The following is our author's description of the church of Paulinus at Tyre, in his letter to that bishop:—

"Thus then, embracing a much wider space, he strengthened the outer enclosure with a wall to compass the edifice, that it might be a most secure bulwark to the whole work. Then raising a large and lofty vestibule, he extended it towards the rays of the rising sun; and, on entering the gates, he has not permitted you to enter immediately, with impure and unwashed feet, within the sanctuary, but leaving an extensive space between the temple and the vestibule, he has decorated and enclosed it with four surrounding porticos, presenting a quadrangular space, with pillars rising on every side. Between these he carried round the frame-latticed railing, rising to a proportionate and suitable height; leaving, however, the middle space open, so that the heavens can be seen, and present the splendid sky irradiated by the beams of the sun. Here, too, he has placed the symbols of the sacred purification, by providing fountains built opposite the temple, which, by the abundant effusion of its waters, affords the means of cleansing, to those that proceed to the inner parts of the sanctuary. And this is the first place that receives those that enter, and which, at the same time, presents to those that need the first introduction, both a splendid and convenient station.

"After passing this, he has made open entrances to the temple, with many other inner vestibules, by placing again three gates on one side towards the rising sun. Of these he constructed the middle one, far exceeding those on each side in height and breadth, embellishing it, at the same time, with exceedingly splendid brazen plates bound with iron, and decorated with sculpture, superadding them, as guards and attendants to a queen. In the same way, after disposing the number of the vestibules, also with the porticos on each side of the whole temple, he constructed above these different openings to the building, for the purpose of admitting more light, and these lights or windows he also decorated with various kinds of ornamental sculpture.

"But the royal temple itself he has furnished with more splendid and rich materials, applying a generous liberality in his expenses. And here it appears to me to be superfluous to describe the dimensions, the length and breadth of the edifice, the splendid elegance, the grandeur that surpasses description, and the dazzling aspect of the works; for when he had thus completed the temple, he adorned it with lofty thrones in honour of those who preside, and also with seats decently arranged in order throughout the whole, and at last he placed the holy altar in the middle. And that this again might be inaccessible to the multitude, he enclosed it with frame-lattice work, accurately wrought with ingenious sculpture, presenting a beautiful appearance to the beholders. And not even the pavement was neglected by him, for this too he splendidly adorned with marble, and then proceeded to the rest and to the parts outside the temple. He provided spacious exhedræ and oëci on each side, united and attached to the church, and communicating with the entrance to the middle of the temple."

Of the above structures, the former is still in existence; not indeed the identical building, but, as there seems reason to believe, a building similar in general form and arrangement. The text of Eusebius is difficult and obscure, and conveys but an indefinite idea of the edifice. Strange to say, we have a plan and description, which may be relied upon as genuine, in our own isles.

At Iona flourished abbot Adamnan, so distinguished by his participation in the great paschal controversy, A. D. 705; and he supplies the architectural antiquary with the knowledge so much desired. We owe the information to a singular contingency. After a long pilgrimage and continued residence in the Holy Land, a Gaulish bishop, named Arculphus, driven to the Hebrides, became the guest of the Culdee monastery. Here he related his perils, describing

the holy places he had visited; and the "*Sebellus de Locis Sanctis*" contains his narrative.

Rarely has any work been transmitted with more peculiarity and authenticity. Adamnan wrote upon his tablets, from the actual dictation of the stranger; the notes so taken became the book we now possess. The Holy Sepulchre, as might be anticipated, was the main object of Adamnan's curiosity; and in addition to the verbal description, Arculphus drew a plan of the buildings upon the tables with his own hand. This plan Adamnan copied in his manuscript; he speaks of his drawing with extreme humility, calling it a vile figuration; but, as will be seen by comparing it with the plan of San Stefano Rotondo, it affords valuable information. The church was wholly of stone, of "wonderful rotundity," supported by twelve columns; having, as it would seem, three aisles; it was entered by four doors; and the sepulchre itself was illuminated by twelve lamps, burning day and night in honour of the twelve apostles. Since Adamnan speaks of three walls, we must suppose that the interior circle marks the columns, and the lines were probably staircases, leading to an upper church or gallery. When Aculphus saw the Holy Sepulchre, it had been somewhat damaged by the Persians, and it was subsequently ruined by the Arabs; yet, as the existing church still retains the original shape, we do not doubt but that it was rebuilt upon the original foundations.

Other churches were built by Constantine, at Jerusalem, Antioch, Nicomedia, Mambre, Heliopolis, Rome, and Constantinople, but few remain to the present day, few, at least, that have not been materially altered. Perhaps the most perfect specimen remaining is the church of S. Constantia; the burial-place of the daughter of Constantine; it is circular in plan, and divided by concentric rows of pillars, from which spring arches to support the roof. The model from which it was constructed was evidently identical with that of the Holy Sepulchre, even were it not that structure itself. It is the opinion of some, that the form of circular churches was derived from that of heathen temples of the same kind, such as those of Vesta, or Minerva Medica; this, however, does not seem to be the case, for although they are both circular in plan, they are of entirely different construction and arrangement. The temple has its columns on the exterior, supporting an entablature, while the church has its detached columns arranged in concentric circles within, connected by arches springing from the capitals, forming one or more aisles; the arrangement, it will be acknowledged, is totally dissimilar, and the mere outline cannot have much weight in the consideration.

But some have gone still further, and claimed the very structures themselves for heathen temples: the building mentioned above is supposed by such to be an ancient temple of Bacchus; but as Mr. Knight, in his beautiful work on this subject, says, "This opinion is principally founded on the mosaics with which the ceiling of the aisles is adorned, and which represents vine-leaves and grapes. But the vine is a Christian emblem, and is so frequently introduced in the decoration of Christian places of worship, that little weight can be attached to this circumstance. The architecture of this building is in conformity with the style of the time of Constantine, and not in conformity with that of a much earlier date." The fact is, the circular is the most natural form for sepulchral chapels, where the chief object is a tomb, placed in the centre. Other similar chapels are still in existence, of which, probably, the most remarkable, is that of S. Stephen. Baptisteries were likewise frequently of the same form, as is that of S. John Lateran, but more frequently octagonal, and sometimes octagonal within and circular without. All such buildings seem to have been simply baptisteries or sepulchral chapels; the form is totally unfitted for the requirements of the Christian liturgy, nor do they seem to have been employed for such purpose, with the exception, perhaps, of the church of the Holy Sepulchre, and this was not purely circular, but had parts of different plan attached to it, something like to the Temple Church, London. The form is very suitable for a baptistery. *See* Round Churches.

The more usual plan of Christian churches is that of a parallelogram, which form is said to have been derived from the heathen courts of justice; but ere entering upon the consideration of this matter, it will be well to give some description of the parts and arrangement of the early Christian churches, as collected from the descriptions of Eusebius above given, and from the writings of other authors who allude to the subject.

From such authorities, it would seem that churches of this period consisted not merely of a building for public service, but also of *exhedræ* or out-buildings, employed for the secular as well as religious concerns of the church; such as schools, libraries, houses of residence for the clergy, &c.; the whole being surrounded and enclosed by an outer wall. This arrangement is very similar to that of our existing cathedrals. That all within this outer wall was considered as belonging to the church, and consecrated ground, is evident from the fact of its being acknowledged as a sanctuary in after times. The position of the church within this enclosure, was generally east and west, having the altar toward the east; but this custom was not always observed, as we meet with many exceptions. That such a custom did prevail in spite of such exceptions, we have the authority of several writers. Socrates, noticing an example of the contrary practice, says, that the church at Antioch stood in a different position to other churches, for that the altar did not look towards the east, but to the west; and a similar observation is made by Paulinus Nolanus, respecting one of his own churches, and he gives the reason for his departure from the usual custom, namely, that the structure was made to look towards another, in memory of the Saint in whose name the latter was dedicated. The Apostolical Constitutions direct that churches should be built toward the east, but Walafridas Strabo says, "The ancients were not nicely curious which way their churches stood, but yet the most usual custom was for Christians to pray toward the east, and therefore the greater proportion of churches were built with respect to that custom."

Allowing this custom to have prevailed then, we shall have our first or outer entrance in the west wall of the enclosure, and this is called by Eusebius the προπυλον μεγα and προτη εισοδη. Through this vestibule, admittance was obtained into a large quadrangle or open area, surrounded by cloisters, which is called by Eusebius, αιθριον and αυλη, and by the Latins, *atrium;* the cloisters being distinguished in the former case by the name of στοαι, and consisting of a covered way, the roof supported by pillars or an open arcade. The object of this court seems to have been to receive the penitents of the first order, or mourners, who were not permitted to enter the main body of the church; in after times it was used for a place of burial, but then only for persons of distinction; kings thinking it a great honour to be buried within the gates. This place was sometimes named *impluvium.* In the centre of the open area was a fountain or large basin of water, in which it was customary for the Christians to wash their hands and face, and perhaps their feet, ere they entered the church, such practice being a symbol of the purity of heart which should attend them there. Tertullian

speaks of the absurdity of going to prayer with washed hands and a polluted soul. A similar custom still prevails in the Romish church, borrowed doubtless from primitive practice, although differing in the intention and object for which it is observed. The fountain is called indifferently, φιαλη φρεαρ, *nymphæum*, *cantharus*, and *leontarium*, the latter term supposed to have been applied from the spouts being sometimes in the form of lions' heads. Socrates, speaking of the skirmish between the Catholics and the Macedonian heretics, says, "Such a slaughter was made, that the court (αυλη) was filled with blood, insomuch that the fountain (φρεαρ) was overflowed therewith, and ran through the adjoining cloisters (στοαι) even into the street." Examples of the atrium in its primitive shape are yet preserved in the churches of San Clemente, San Lorenzo, San Paolo, San Georgio in Velabro, Sta Maria in Trastevere; remodelled in San Giovanni Laterano, and Sta Maria Maggiore, and rebuilt in modern shape in St. Peter's. At San Ambrogio, Milan, the atrium is fully as large as the nave.

Entrance was obtained from the atrium into the *pronaos* or *narthex*, through three gates, of which the central one was frequently the largest and most important. The narthex formed the first division in the body of the church, and was used as the station for the catechumens, and such of the penitents as came under the title ακονομενοι, or hearers, so called from the circumstance of their being allowed to listen to the lessons and sermon, to which privilege also Jews, heathens, heretics, and schismatics were admitted, in this part of the church. Here also, somewhat in advance, stood the *substrati*, or third class of penitents, so called from the custom of prostrating themselves before the bishop, after sermon was ended, to receive his benediction. There were frequently more nartheces than one in a church, that of Sta Sophia is said to have had no less than four.

We have now arrived at the ναος, or nave, the principal division of the church, in which the body of the faithful, those who were under no censure, and in full communion with the church were congregated. This part was separated from the narthex by rails of wood, and was entered by gates which are distinguished by writers as πυλαι καλαι, or βασιλικαι, the beautiful or royal gates, so named perhaps from the circumstance of kings laying aside their crowns at this place, ere they proceeded further into the church. Leo Grammaticus notices it as a flagrant want of reverence in the emperor Michael, that "when he came to the royal gates, he did not lay aside his crown, as kings were used to do."

It was a practice with the early Christians to separate the sexes in public service, one portion of the church being allotted to the males, and another to the females. The author of the Apostolical Constitution speaks of this separation as usual in his time, for he says, "Let the doorkeepers stand at the gate of the men, and the deaconesses at the gate of the women;" and S. Cyril says, "Let men be with men, and women with women, in the church." Socrates also remarks of Helena, that "she always submitted to the laws of the church in this respect, praying with the women in the women's place." In some cases, the women were placed on the north side of the church, but probably this was not an universal practice; in the Greek church the galleries were reserved for the women. Besides this, there was a further subdivision, distinct positions being allotted to virgins, widows, and matrons. In the Apostolical Constitutions, the virgins, widows, and aged women were placed in the highest rank, and the matrons behind them. In this manner were the communicants disposed in the nave, but besides them the fourth or last order of penitents were admitted into this part of the church; they were called *Consistentes*, and were allowed to remain during the celebration of the Eucharist, although not to participate.

At the farther end of the nave, was the choir, which was divided from it by a low wall or wooden partition; here were located the singers, and here also the gospel and epistles were read from the *ambo*, or pulpit. This was an elevated desk, ascended by several steps, which S. Cyprian calls *pulpitum* and *tribunal ecclesiæ*, and which was elsewhere called βημα γνωστων. Bona cites Prudentius to prove that the bishops and priests made their sermons from this pulpit, but this seems to be a mistake, for the bishops anciently addressed the congregation from the steps of the altar, as is evident from Valesius. S. Chrysostom, it appears, did preach from the ambo, but only in order that he might be the more audible to the people; such was not the usual custom. A very perfect example of the form and arrangement of the choir still remains in the church of San Clemente.

We now arrive at the last division, which answered to the holy of holies of the Jewish temple, being appropriated to the priests and the celebration of the most sacred offices of the church. Eusebius calls this place αγιασμα; and it is elsewhere named αγιον, or the sanctuary. The Latins call it *sacrarium*. The term θυσιαστηριον, which is more particularly applied to the altar, is sometimes used to denote the whole sanctuary, as is evident from the decrees of the council of Laodicea, which forbid lay persons entering the θυσιαστηριον. A more common appellation is that of βημα, which is so employed from the circumstance of this part of the church being elevated above the nave by a series of steps. A further separation was effected by means of rails, or lattice-work, named *cancelli*; whence our term *chancel*. In his description of the church of Paulinus, Eusebius states the office of these cancelli to be the rendering the sanctuary inaccessible to the multitude; and the council of Trullo directs, "that no layman whatsoever be permitted to enter the place of the altar, excepting only the emperor, when he makes his oblation to the Creator, according to ancient custom." A similar order of the council of Laodicea has been given above. From this practice, the sanctuary obtained the epithet αδυτα, αναβατα, *inapproachable*. This part of the church was usually of a semicircular plan, around the circumference of which, in close proximity to the wall, were ranged the seats for the bishop and clergy. The throne of the bishop was in the centre, immediately behind the altar, and raised to a greater elevation than those of the presbyters, which were ranged on either side of him. Gregory Nazianzen speaks of himself, as bishop setting upon a high throne, with the presbyters, on lower benches, on either side.

The altar was situate in the centre of the chancel, in front of the bishop's throne, so as to allow of a passage all round it; it was named indifferently *ara*, *altare*, θυσιαστηριον and βωμος; the latter, however, qualified by the addition of αναιμακτον. The most ancient altars were of wood, as we learn from several passages in the Fathers: amongst others, S. Austin, speaking o an outrage by the Donatists against a Catholic bishop, says, "They beat him cruelly with clubs, and such like weapons, and at last with the broken pieces of the wood of the altar." Optatus, again, speaking of the Donatists, says, "They brake the altars in such pieces as would afford them plenty of wood to make new; but where there was a scarcity of wood, they contented themselves with scraping them, by way of pretended expiation." When stone altars began to be employed, is very uncertain; all that can be determined upon this point is, that the material was in use for such purpose in the time of Gregory Nyssen, but how long before we cannot tell. Gregory, speaking of the sacred character of the church and its furniture, says, "This

altar whereat we stand is by nature only common stone, nothing different from other stones, whereof our walls are made and our pavements formed; but after it is consecrated and dedicated to the service of God it becomes a holy table, an immaculate altar which may not promiscuously be touched by all, but only by the priests in the time of divine service." In the next century, a decree was passed at the council of Epone, that no altars should be consecrated, but such as were of stone. The Pontificals speak of silver altars dedicated by Constantine. The early wooden altars were similar in shape to tables, but when stone was employed for this purpose they assumed a somewhat different appearance, consisting either of slabs supported by a central pier, or of a structure built up similar to a sarcophagus, or tomb.

The altar was covered by a canopy, supported by pillars, frequently twelve in number, in allusion to the number of the apostles, and having their capitals adorned with silver bowls. The canopy which was spherical, was surmounted with a cross and the space between the pillars hung with veils, which served to conceal the altar. These are, perhaps, the veils alluded to by Chrysostom, where, speaking of the consecration of the elements, he says, "When you see the veils withdrawn, then think you see heaven opened, and the angels descending from above." Curtains, however, were used in other parts of the church, before the doors, and at the entrance to the sanctuary, which were sometimes richly adorned with gold, as was that given by Chosroes to the church at Antioch. Epiphanius relates his tearing to pieces a veil suspended before the doors of the church, because it had a picture on it; and Athanasius, speaking of the enormities of the Arians, says, "They took the bishop's throne, and the seats of the presbyters, and the table which was of wood, and the veils of the church, and whatever else they could, and carried them out and burned them." Sometimes a silver dove was suspended over the altar. The canopy was turned *ciborium*, or πνργος. In later times, crosses were set upon the altar, but the time of their introduction is not known: Sozomen and Evagrius are among the first who allude to the practice. The altar was covered with a linen cloth, as is evidenced by Optatus, who, in allusion to the extravagant pretensions of the Donatists in purifying everything that had been touched by the Catholics, says "that if anything was polluted, it must be the covering, and not the tables;" and adds, that they pretended to wash these palls. Sometimes such coverings were of richer stuff, for Palladius has reference to some Roman ladies, who bequeathed their silks to make coverings for the altar. The sacred vessels were of various materials. We learn from Irenæus, Epiphanius, and Jerome, that chalices were made of glass in their time; but there can be no doubt that silver and gold were frequently employed for this purpose; for it is related of Laurentius, who was martyred in the time of Valerian, that he would not deliver up the plate in which they were used to celebrate the sacred mysteries; and in an inventory delivered up at the same period, by Paul, bishop of Cirta, we find mention made of two gold cups, six silver cups, and various other vessels of the same materials.

In many churches, besides the altar, was a side-table, in a recess, on one side of the *bema*, where the offerings of bread and wine were received, and which is called by various names, παρατραπεζα, *prothesis*, *paratorium*, *oblationarium*, and *corban*. In the recess on the opposite side of the bema, was the *Scenophylacium*, which was a sort of vestry in which the priests robed, and where the deacons brought the vestments and vessels from the Diaconicum, previous to service. It was likewise called the *Diaconicum Bematis*, to distinguish it from the larger building of the same name and uses outside the church.

Under the general term *exhedræ*, are comprehended all the buildings that were contained within the outermost enclosure, but without the walls of the church, properly so called: these were many in number consisting of schools, residences for the priests, &c.; but we shall here only take notice of the more important.

The *Baptistery*, during the first five centuries, formed a separate building outside the church, as we gather from Eusebius, Paulinus of Nola, and Gregory of Tours. It was a large and capacious edifice, containing several apartments, some perhaps for the catechumens, and was not unfrequently octagonal in plan. It was necessary that these buildings should be somewhat extensive, for the sacrament of baptism was but seldom celebrated, the two seasons set apart for the purpose being Easter and Pentecost; so that a large number of persons were congregated together at the same time; and there is reason to suppose that there was but one baptistery to each city, however numerous the churches may have been. In the centre of this building was the font, which was large enough for immersion.

The *Secretarium*, or *Diaconicum*, was a building in which all the property belonging to the church, such as vestments, vessels, offerings, &c., were deposited when not in use, and whence they were carried into the church when required. It was called diaconicum from the fact of the deacons having charge of all matters contained therein.

Another outbuilding was the *Library*, as we learn from Eusebius, who tells us that he was greatly indebted to that founded by Alexander, bishop of Jerusalem, in procuring materials for the compilation of his history; and Julius Africanus is said to have founded another at Cæsarea. The largest library was probably that belonging to the church of Sta Sophia, Constantinople, which is said to have contained one hundred thousand books, and was burned down by the firing of the city in a proper tumult. That *Schools* were attached to the church, we may know from what Socrates says of Julian, "that, in his youth, he frequented the church, where, in those days, the schools were kept."

Amongst the exhedræ are likewise reckoned the *mitatorium*, *gazophylacium* and *pastophoria* but of these we know little or nothing.

As regards the decoration of the interior of the church, we may gather, that the walls were sometimes coated with marble, and most frequently adorned with inscriptions of passages of Scripture, or other religious writings appropriately disposed. Thus S. Ambrose speaks of the text, "There is a difference between a wife and a virgin," &c., being written on the walls near the virgins' seats; Paulinus mentions several passages applied to the same purpose, as do also Sidonius and Apollinaris. The roofs were enriched with mosaic, or what is called lacunary or panel-work, and in this case gilding and colour were employed; in the church of Sta Sophia is an instance of the former practice, and in that of Constantine at Jerusalem, an example of the latter, where the roof was panelled, and covered with gold. S. Jerome likewise speaks of lacunary golden roofs, walls adorned with marble, pillars with capitals of shining gold, gates inlaid with ivory and silver, and altars set with precious stones and gold. Such was the arrangement and decoration of an early Christian church.

We have already considered the question relative to the conversion of heathen temples to the purposes of Christian worship; but there is yet another building in use amongst the pagans, which lays claim to the same honour, and with some greater show of probability, it is the *basilica*. The Roman

basilica was the hall of public justice, the court in which, during the early history of that nation, the kings sat to hear and decide the causes of their subjects; it was, in fact, at that period a royal palace situate in the Forum, whence the name. The word, however, is Greek, and was first applied to the portico in the Athenian Ceramicus immediately beneath the Pnyx; the custom, as well as the building, was borrowed by the Romans. Such edifices varied in form in different instances, but not to any very great extent, the same disposition seems to have been universally observed and was as follows:—

The plan was an oblong, terminated at one, or sometimes both ends, with a semi-circle; the semi-circle was occasionally omitted, and sometimes there were two or three of different dimensions. Internally the breadth was divided into three—rarely into five—by two or four rows of columns running down the length of the church; at the extreme end was the semi-circular apse, in the midst of which was the seat of the prætor, whence he administered justice; this was the tribunal. On either side of the prætor, but lower down, were the benches for his assessors, the centumviri, and other officers, and all these were separated from the other part of the building by an enclosure of lattice-work, to which was given the name of *cancelli.* Outside of this screen was a place allotted to the notaries and advocates, the remainder of the building being occupied by the people.

We have here a three-aisled structure, the divisions being formed by two central rows of columns and two outer walls, the columns frequently supporting a gallery in the outer divisions. The central portion was generally lighted from windows or openings in a wall raised above the columns, thus forming a sort of clere-story. This roof was invariably of wood, and did not always cover the whole building. For a further description *see* Basilica.

Some writers suppose that several such buildings were delivered by Constantine into the hands of the Christians, and were employed by them as churches, or places of public worship. Some go so far as to assert, that they were the prototype of the succeeding churches, not only in form but in the division and disposition of the parts. The writer we have had occasion to quote in a previous part of this article speaks thus:—

"Had the basilica, such as we have described it, been planned for the express reception of a Christian congregation, it scarcely could have received a more convenient or appropriate form—none more happily combining magnificence with utility—none more consonant to the ideas which then prevailed. The general shape of the church as prescribed by the Apostolical Constitutions, was to be an oblong like unto a ship, that is, to the vessel of the ark. Does not the outline of the ground-plot of the basilica entirely meet the suggestion? and the terms *nave*, *nef* or *vaisseau*, applied to the main portion of the edifice, show how enduringly the idea prevailed in subsequent ages. The apse in which the prætor administered justice, surrounded by the centumviri and other judges offered a dignified tribunal for the bishop and his clergy; the dark chambers below suggested the subterraneous chapel, in which might be deposited the remains of saint or martyr. The enclosures, the *cancelli* for the notaries and advocates, might receive the singers of the choir. The lengthened aisles would furnish space for the congregation of the faithful: the galleries seclude the women; and the porch fronting some of the basilicas, or the uncovered portion which, if separated from the rest by a wall, would constitute a court, was prepared for those who had been separated from the rest of the congregation by their sins, or were not yet allowed to participate in the sacraments. Hence we find from one of those incidental notices which often are more instructive than the set narrative of history, that the basilica had been given up, bodily, for the purpose of Christian worship. A poet, but also a rhetor, addressing an emperor, tells him that these structures, heretofore wont to be filled up with men of business, were now thronged with votaries praying for his safety; '*Basilica olim negotiis plena, nunc votis pro tua salute susceptis.*' This occupation of the Roman basilicæ was, nevertheless, only transitory. They did not become the abiding-places of the faith. Why was this privilege denied them? In situation they were most convenient, placed in the centre of business and population; their plan and form so convenient as to invite the purposes of worship. Unpolluted by the idol or sacrifice, they were free from the recollections rendering the heathen temple odious. With the smallest proportionate expense or labour, the basilicæ of the Forum might have been rendered the most stately and dignified of sanctuaries. Yet they fell! Only one example can be found of a secular basilica actually converted into a Christian church—and that example, memorable as it is, does not exist in Rome. As if for the purpose of constantly demonstrating to mankind the visible triumph of the spiritual kingdom, every stage in the early development of the empire of Christianity seemed destined to efface the honours of heathen sovereignty. The Christian basilica, though entirely modelled upon the heathen basilica, and constructed with the spoils of the basilica, was therefore fated to be its ruin and destruction.

"A single cause suffices—a cause of which we now can scarcely appreciate the potency. Veneration for the graves of the martyrs, as an almost irresistible motive, attracted the Christian basilica away equally from the precinct of the secular basilica as from the site of the heathen temple. By determining the locality assigned to the Christian edifice, this feeling necessarily determined the neglect, ruin, and destruction of the proud monuments of senators and Cæsars. The demolition of earlier structures, for the purpose of furnishing materials, had already been long practised. Thus the interior of the Coliseum displays the friezes and fragments, mixed up in confusion, amidst the masonry of the beautiful yet appalling circuit of its walls. These, perhaps, may have resulted from the removal of other buildings previously existing on the site; but under Constantine similar demolitions proceeded, as it should seem, equally from the desire of sparing expense, and the increasing inability to execute works of art. The splendid Forum of Trajan, which had excited Constantine's admiration, fell at his command, and furnished by its spoils the decorations of the arch of the first Christian emperor. Abandoned for more hallowed ground, the civil basilicas were destroyed, and the columns which supported them transported to the new sites, where they arose in lengthened perspective and barbaric splendour. By their very aspect, such of the Christian churches as retain their original features, show the haste and unskilfulness with which they are reared; one capital cut through and deprived of the lower range of the acanthus, to fit it into the required space; another projecting over the shaft; a third shrinking within; a fourth, the leaves blocked, and prepared for the touch—never to be given—of the chisel that was to have imparted Corinthian elegance;—the columns themselves of unequal circumference or unequal height, deprived of their due proportions, or rudely stilted to attain the necessary elevation. The richest materials are mixed with others of inferior quality; pavonazzo and verd antique, the products of the quarries of Syene or of Paros, and the homely Travestine, are intermingled without choice or discrimination."

This writer is of opinion that the heathen basilicas were

not actually converted into Christian temples; there are many, however, who hold the contrary, amongst whom is Mr. Hope, who cites, as examples of such adaptation, the Sessorian basilica, and that in the palace of the Lateran, which he says were given to the church by Constantine. The strongest argument on this side, is, we think, the triumphant declaration of Ausonius, that the ancient halls of justice were filled with Christian worshippers; the above-mentioned reviewer alludes to this passage in the following words:—

"We have already seen that no one of the Christian basilicæ at Rome, resulted from any adaptation of the civil structures of heathenism to religious purposes. The columns fell, to rise in new localities. Rome furnishes no example of a basilica preserved by its application to Christian worship. No confirmation is given in the ancient capital to the orator's assertions, exulting, in the presence of Gratian, at the crowds which filled the ancient halls of justice, then, as he boasts, resounding with hymn and praise; yet we can point out one city in which his assertions are not a rhetorical phrase, but a truth. Do we seek for the verification of the words of the poet-rhetor, 'Basilica, olim negolus plena, nunc votis pro tua salute susceptis?' Here we find that which at Rome we search for in vain. Here alone can we behold the one example of a basilica consecrated as a Christian church, in which you enter, and see the Corinthian capitals just displaying their graceful foliage, mutilated and yet distinct—through the rude wall which encircles them—whilst the shaft of another, displaced and broken, lies in gigantic bulk before the portal of the edifice. This indeed is the very city in which the poet-rhetor was speaking—for he is Ausonius—and the city is Treves. The ancient capital of the Roman empire beyond the Alps, furnished the model for the structures, which, far more than those of Rome herself, assisted in the development of Christian architecture."

We cannot think this a satisfactory method of getting over the difficulty; Ausonius seems to speak of such facts as well and universally known; he is describing the general effect of Christianity, and glorying in its success; his are sweeping assertions, not applicable to merely individual instances, but to general custom. Besides, if the Christians at Treves converted basilicas into churches, why should they not do the same elsewhere? and especially in the metropolis, where there was a larger proportion of such buildings, and greater need of churches.

While saying this, we do not mean to deny that there was a strong repugnance amongst the early Christians to everything that had been connected with paganism, and that the application of the basilica was rather a matter of necessity than of choice. When Constantine legalized Christianity, the Christians numbered somewhat considerably, and no doubt increased rapidly upon that event; many who previously favoured that religion, but were fearful of the consequences of an avowal, now openly professing it. Churches were needed more than ever, and they had not skill wherewith to erect them; what could be done? where were churches to be found, while new ones were building? were there any existing buildings that could be adapted to such a purpose? The pagan temples were not fitted for such uses, even had there been no repugnance to their origin; but the basilicas would answer the purpose well, as far as their construction was concerned, nor were there equal objections to them on the score of their previous employment. What more likely than that they should be used at least for a time, until new structures could be erected?

The counter-argument arising from the absence of any examples of such adaptation of the civil basilica, may be accounted for without much difficulty: they were destroyed, to afford materials for new structures in other sites. The principal cause of their destruction or removal, is to be sought in the veneration of the Christians for the graves of the martyrs. On this subject, Mr. Knight says:—

"From the custom which had originated in the catacombs—from the habit which the primitive Christians had acquired of visiting the graves of the martyrs; it became a matter of necessity to associate the church with the tomb, and to provide a place of worship below ground, as well as above. This, in several instances, was accomplished at Rome by placing the church immediately above a part of the catacombs, as at San Lorenzo and Santa Agnese; or, as at St. Peter's, by placing the altar immediately above the spot to which the mortal remains of the apostles had been removed.

"The practice of associating the churches with the graves of martyrs, was the cause of their being frequently placed in situations which had little reference to public convenience; namely, without the walls of the cities to which they belonged; for, as executions usually took place without the walls, and as the martyrs were often buried, or supposed to have been buried, where they were put to death, the wish of that age could not be accomplished without frequently placing the churches in remote and insulated situations. Thus it was that Constantine placed the church of St. Peter adjacent to the circus of Nero, though the city of Rome was, at that time, at some distance from the Vatican Hill. Theodosius, for similar reasons, placed the church of St. Paul at an equal distance from the city on the opposite side. At that time, a liability, which afterwards exposed insulated churches and their frequenters to much peril, did not exist. At that time, the interior of the empire was still inviolate, and those who built the churches never imagined that the day might come, when their descendants could not go out of the walls without being liable to attacks, and when the churches themselves would be exposed to insult and injury. Little did Constantine imagine, that men of a newer religion than his own would ever reach and deface the cathedral which he had planted within sight of the metropolis of the world."

The existence of such a feeling amongst the early Christians, coupled with the circumstance of the tombs of martyrs being usually without the walls, and the prevalent custom of employing the materials of old buildings for the construction of new, will account, as we think, satisfactorily for the want of more tangible evidence of the conversion of the heathen basilica to Christian uses.

While we contend thus far, we do not wish to ally ourselves with those who maintain, that the arrangement of churches was derived from that of the civil basilica: there is no doubt a similarity of distribution and a certain analogy between the purposes which each division in either building served; still, there are strong grounds for believing that such disposition in the churches arose from the natural requirements of the religion, rather than from any extraneous influence. The description of the several orders of penitents, and of their positions in the church, as above given, is sufficient proof of such being the case, for that was written during times of persecution, before Constantine had ascended the throne; the division into parts, therefore, was determined long ere any basilicas were given up for Christian worship. It is not improbable, however, that the form of later churches was derived from that of the basilica; for it must needs be, that either some existing form was copied, or an entirely new idea originated. That the latter was the case is very improbable, from the nature of things, almost all novelties having emanated, in some degree or other, from things previously existing: but, besides this, such an

occurrence was more especially improbable at the period alluded to, when art was falling to decay, and its influence was not strong enough even to retain previous acquirements, much less to originate new. The main features in the churches erected immediately after the establishment of Christianity, with the exception of Constantine's circular buildings, were those of the civil basilica: there were some few alterations and additions, it is true, to adapt the form to the requirements of the church; but these were at first not very considerable, although extended farther in after times. Of these were the atrium and out-buildings; and, in later times, transepts. With regard to the latter, it has been argued by some, that they are to be found in the civil structures; at least, in the internal arrangement; but this we think almost too nice a similarity. There was, indeed, a cross-passage at the end of the nave, so to speak, but we can scarcely set it down as the prototype of the transept. The cross-form originated in Christian symbolism; nor does it appear even in churches of the earliest date. The Apostolical Constitutions allude to churches as being in the form of a ship, and such seems to have been the actual shape of the first buildings. The cross-plan was a gradual development. At first, we find the cross a prominent feature in the internal decoration, as at St. Clement's, where the paving of the nave is arranged in that form; and afterwards forming an essential office in the construction, as in the Byzantine churches, and the later basilicas. We are of opinion, then, that, at the onset, civil basilicas were employed for Christian worship, though rather as a matter of necessity than choice; that the division and disposition of parts observable in the early churches was not derived from the basilica; but that their form and construction was so derived; and that hence was developed the form of churches in after ages.

As regards the styles of architecture employed, the earliest constructions can scarcely be said to belong to any style; they were composed of the ruins of heathen structures, promiscuously heaped together; columns from one building, entablature from another; or even one column from one building, and the next from a second; and not unfrequently the shaft or base of one column with the capital of another: columns of different heights and proportions were huddled into the same row, and the difference of level made up either by stilting or cutting short. The Byzantine churches, with their square plans and spherical roofs, are the first buildings which can be said to possess any style, and these were chiefly confined to Asia Minor, having little influence in Italy until the sixth century. (See, BYZANTINE ARCHITECTURE.) Shortly after this, the Lombards established themselves in Italy; and although they brought with them no architecture of their own, they gave a somewhat novel character to the buildings erected by them, the difference being principallly in detail. This style prevailed in the north of Italy up to the end of the twelfth century, at the commencement of which some marked alterations were introduced. (See, LOMBARDIC ARCHITECTURE.) To this succeeded that most perfect form of Ecclesiastical Architecture, pre-eminently termed the Christian style, which has prevailed, with some interruptions, ever since; we need scarcely add, we allude to the Gothic, or pointed, which for its solemn grandeur, as well as for its perfect construction, is, of all, the most appropriate for a Christian temple.

We have now arrived at the conclusion of this interesting subject, and for any further information must refer to such articles as CHURCH, CATHEDRAL, GOTHIC, and SAXON ARCHITECTURE, &c.

ECHINUS (from εχινος, a word denoting the prickly cover of a chesnut) a convex moulding in the form of a conic section, generally carved into ornaments representing truncated spheroids, or eggs, with the upper ends cut off, the upper part of the axis projecting, and the lower part receding. Each truncated spheroid is surrounded with a border, of an elliptic figure, in close contact, showing something more than a semi-ellipsis, the shorter axis being horizontal.

The projecting edge of the border is in the surface of the moulding, previously wrought, as is also the curvature of the upper part of the spheroid. Every two adjacent borders contain a space equal to the thickness of the border at the top, and gradually receding towards the bottom. In each recess, or space, is an anchor, or tongue; the front edge of which comes in contact with the surface of the original moulding, and is in a vertical line cutting the surface of the moulding at right angles.

In Grecian architecture, the front of each border, and also the front of each tongue, or anchor, is wrought to an angle, the section of which inclines equally to the surface. The bottom of the spaces on each side of the tongue, on the under side, is nearly in the same surface as the recess on the sides of the eggs.

In Roman architecture, the general contour is the segment or quarter of a circle, and the fronts of the surrounding borders are not brought to an angle, but remain as part of the moulding, either plain or with a hollow sunk between the edges, leaving a fillet next to each edge.

Its situation in an order, is in the entablature or capital, but never in the base.

In the original Doric order, the ovolo, which crowns the cornice, and that of the capital, are never carved. In the Ionic and Corinthian entablatures, it may either be carved or not, but in the antiques it is generally carved. The ovolo in the capitals of these orders, is, however, always carved into the ornaments we are describing. The French call this moulding, *quart de rond;* the English, *quarter-round*, or *boulting;* the Italians, *ovolo;* the Latins, *ovum*, from its being usually carved with the figures of eggs; and the French, for the same reason, sometimes call it *œuf.*

ECHO, (from the Greek, ηχος, *sound*, of the verb, ηχεω, *I sound,*) the reverberation of sound, occasioned by the particular construction of a vault or wall, the section of which is most commonly of an elliptical or parabolical figure. The method of making artificial echoes, is taught by the Jesuit Blancani, in his *Echometria*, at the end of his book *On the Sphere.*

We are informed by Vitruvius, that in various parts of Greece and Italy, there were brazen vessels, ingeniously arranged under the seats of the theatres, to render the sound of the actors' voices more clear, and make a kind of echo; by which means the prodigious multitude of persons present at their spectacles were enabled to hear with ease and pleasure.

The distribution of sound in public edifices, so that the echoes may be most advantageously brought to strengthen the original sound, is a subject practically deserving much attention. In Sir J. Herschel's Treatise on Sound, the reader will find some sensible observations on the errors of architects in this respect. The inattention of the latter to the effect of the reverberation of sound, was curiously exemplified in the cathedral of Girgenti, where the confessional was placed in a focus conjugate to another and unenclosed part of the church; by which unlucky error the echo was instrumental in informing a husband of the infidelity of his spouse. In many of our public buildings, though professedly erected for purposes where the proper distribution of sound is of paramount importance, it is no uncommon occurrence, that one part of the audience pos-

sesses a monopoly, while the remainder witness the ceremony or performance in dumb show.

Sounds are reflected by certain configurations of bodies, like the reflection of light from polished surfaces; so that if a person situated before one of these bodies utter a word, he will in a short time after hear the echo, or repetition of the sound. The vibratory motion of the air, which constitutes sound, is reflected by hard bodies, and, in certain cases, even by fluids. Thus the sides of a hill, houses, rocks, banks of earth, the large trunks of trees, the surface of water, especially at the bottom of a well, and sometimes even the clouds, have been found capable of reflecting sounds. The configuration of the surface of these bodies, is much more concerned in the production of the echo than their substance. A smooth surface reflects sounds much better than a rough one. A convex surface is a very bad reflector of sound; a flat one reflects very well; but a small degree of concavity, particularly when the sounding body is in or near the focus of concavity, renders the surface a much better reflector, and the echo is heard considerably louder.

Thus, in an elliptical apartment, if the sounding body be placed in one focus, the sound will be heard much louder by a person situated in the other focus of the ellipsis, that in any other part of the room. In this case, the effect is so powerful, that even when the middle part of the room is wanting, the sound expressed in one focus will be heard by a person situated in the other, but hardly at all by those who stand in the intermediate space.

Without attempting to explain the manner in which the vibrating air impinges upon, and is sent back by, the reflecting body, which would lead us too far into the science of acoustics, we shall briefly notice the following ascertained facts.

If a person standing before a high wall, a bank, a rock, &c., at a certain distance, and uttering a word with a pretty strong voice, or producing by a hammer, stone, &c., any short, sharp sound, hear a repetition of that word or sound, he will find that the time elapsed between his uttering the word, or striking with the hammer, and hearing of the echo, is equal to the time that a sound is known to employ in going through an extension of twice the distance between him and the reflecting wall, rock, &c.; for the vibratory motion of the air must proceed from the sounding person to the wall, &c., and back again from the latter to the former. Now, sound is known to travel at the rate of about 1,125 feet in a second of time; therefore, if the person who expresses the word, or any sound whatever, stand at the distance of 1,125 feet from the echoing wall, &c., two seconds of time must elapse between his uttering the sound and his hearing the echo. If the distance be equal to 4,500 feet, then eight seconds of time must elapse between the uttering of the sound, and the arrival of the echo; and so on. But the same original sound and the echo may be heard by persons at different distances, both from the original sounding-place, and from the reflecting body. The effect, however, will not be exactly uniform, for those who are nearer to the reflecting body, will hear the echo sooner than persons more remote. A situation may be easily found, from which they will hear both the original sound and the echo at the same instant, and as both sounds coalesce, they will only appear as one loud sound, without the echo.

But though several persons, in different situations, may hear the echo of the same sound, yet the echo will be heard better in one particular direction than in any other; now if two straight lines be drawn from the middle of a reflecting surface, one to the place from which the original sound proceeds, and the other to the above-mentioned best direction, those two lines will be found to make equal angles with the surface. Hence it appears, that in the reflection of sound, the angle of incidence is equal to the angle of reflection. Therefore, if a person wishes to hear the echo of his own voice in the best possible manner, he must stand in a direction perpendicular to the reflecting surface. And this shows, that though sound proceeds from an original sounding body, or from a reflecting surface, in every direction; yet a greater quantity of it proceeds in some particular direction than in any other, which is probably owing to the original impulse being given to the air more forcibly in one direction than in another, or from want of perfect freedom in the aërial fluid.

Several phenomena may be easily explained upon the above-mentioned property of sound: for instance, several reflecting surfaces are frequently so situated with respect to distance and direction, that a sound proceeding from a certain point is reflected by one surface first, then by a second, soon after by a third, and so on, but by all in one direction; in which case a multiplied tautological echo is produced; that is to say, the same word is heard repeated several times successively in the same tone and accent; the expression of one Ho! will appear like a peal of laughter; a musical instrument, properly played, will produce an agreeable repetition of as many instruments of the same sort, imitating each other.

According to the various distances of the speaker, a reflecting object will return the echo of several, or of a few syllables, for all the syllables must be uttered before the echo of the first syllable reaches the ear; otherwise it will make a confusion. The farther the reflecting object is, the greater number of syllables will the echo repeat; but the sound will be enfeebled nearly in the same proportion, till at last the syllables cannot be heard distinctly. When the reflecting object is too near, the repetition of the sound arrives at the ear whilst the perception of the original sound still continues, in which case, an indistinct sounding noise is heard. This effect may especially be observed in empty rooms, passages, &c., because, in such places, several reflections from the wall to the hearer, as also from one wall to the other, and then to the hearer, clash with each other, and increase the indistinctness.

From what has been said, it will be easily conceived, that with respect to echoes, a vast variety of effects may be produced, by varying the form, the distance, and the number of reflecting surfaces; and hence we hear of various surprising echoes being met with at different places.

In Woodstock Park, near Oxford, there is a famous echo, which repeats seventeen syllables in the daytime, and twenty at night, when the air is somewhat more dense. On the north side of Shipley Church, in Sussex, there is another remarkable echo, which, in favourable circumstances, repeats twenty-one syllables. At Rosneath, near Glasgow, in Scotland, is an echo, that repeats three times, completely and distinctly, a tune played with a trumpet.

Whispering-places, are those where a whisper, or other small noise, is conveyed from one part to another, at a great distance. They depend upon this principle, that the voice, being applied to one end of an arch, easily passes by a repetition of reflections to the other.

Hence sound is conveyed from one side of a whispering gallery to the opposite one, without being perceived by those who stand in the middle. The form of a whispering-gallery is that of a sphere, or the segment of a sphere. The principle of whispering being that of continued reflection. If a person whisper softly against a wall, the rays which proceed from his mouth issue in all directions against the wall; we shall only

take the rays which emanate from the whisperer's mouth (which we shall suppose to be a point) in a horizontal plane, then it is evident, that they will proceed to the right and to the left, and each particle of sound, as we may call it, for want of a more specific name, will cut off equal segments of the circle which forms the section of the wall; or, in other words, will pass along equal chords; and there will be an infinite number of such reflections; each particle describing chords different from those described by another, and an indefinite number of these will divide the semi-circumference into parts all equal to each other, in the same system of chords; therefore, all the describing particles of sound passing along the equal chords, will meet upon the other extremity of the diameter opposite the whisperer, and thus form a loud whispering noise. It is evident, that polished surfaces are the most favourable for this purpose. Accordingly, all the contrivance requisite in whispering-places is, that near the person who whispers, there may be a smooth arched wall, either cylindric or cylindroidic; though a body with circular sections will do, but not so well.

The most considerable whispering place in England, is the whispering gallery in the dome of St. Paul's Cathedral, London, where the ticking of a watch may be heard from side to side, and a very easy whisper be sent all round the dome. The famous whispering-gallery in Gloucester Cathedral, is no other than a gallery above the east end of the choir, leading from one side thereof to the other. It consists of five angles, and six sides, the middlemost of which is a naked window; yet two whisperers hear each other at the distance of twenty-five yards.

ECHOMETRY, the art of constructing vaults to produce echoes.

ECPHORA, or Ecphoran (from ἐκ, *out*, and φερω, *I bear*,) the projecture, or distance between the extremity of a member, or moulding, and the naked of the column, or other part it projects from.

Some authors, however, account the ecphora, or projecture, from the axis of the column, and define it to be a right line intercepted between the axis and the outermost surface of a member, or moulding. The word is used by Vitruvius, in Chapter III., book iii., in the explanation of columns and their ornaments. See Projecture.

ECTYPE (from the Greek): αρχετυπον, denotes the original, or model; εντυπον, the copy or image, moulded or struck *in creux;* and εκτυπον, the image *in relievo*, or embossed.

EDDYSTONE LIGHTHOUSE, a celebrated building erected upon a cluster of very dangerous rocks, situated in the English Channel, in latitude 50° 3′ N., and longitude 40° 21′ W. These rocks are about fourteen miles from Plymouth Sound, and, lying nearly in the track of vessels going up or down channel, have been the cause of many shipwrecks. To guard against these disasters, it was deemed necessary to erect a lighthouse; but to effect this in a complete and permanent manner, so as to resist storms and afford light, was a task of extreme difficulty.

The Eddystone rocks are so peculiarly exposed to the swell of the ocean from the south and west, that the heavy seas break upon them with uncontrolled fury. Sometimes, after a storm, when the sea is apparently quite smooth, and its surface unruffled by the slightest breeze, the ground-swell, or under-current, meets the slope of the rocks, and the sea beats tremendously upon them, and even rises above the light-house, overtopping it for the moment, as with a canopy of frothy wave. Notwithstanding this awful swell, Mr. Henry Winstanley undertook, in the year 1696, to build a light-house on the principal rock, for the rest are under water; and in 1700 he completed it. So confident was this ingenious mechanic of the stability of his edifice, that he declared his wish to be in it during the most tremendous storm that could arise. This wish he unfortunately obtained, for he perished in it, during the dreadful storm which destroyed it, November 27, 1703. Another light-house, of a different construction, was erected of wood, on this rock, by Mr. John Rudyerd, in 1709; which being consumed by fire in 1755, a third, of stone, was begun by the justly celebrated Mr. John Smeaton, April 2, 1757, and finished August 24, 1759, which has hitherto withstood the attacks of the most violent storms. The following account of this building, taken from Mr. Smeaton's "Narrative," must be read with interest, as a noble instance of the triumph of skill, science, and perseverance over obstacles of the most formidable character:—

Mr. Smeaton begins his account with a general description of the Eddystone rocks, the course of the tides, their situation, component matter, and the proper season for visiting them. He then takes an ample view of Mr. Winstanley's edifice, to whom he ascribes great praise for having undertaken and achieved what had been generally deemed impracticable; and after deploring that gentleman's disaster, goes on to describe the second lighthouse, built by Mr. Rudyerd, as a most complete edifice of the kind, being of timber, in the course of which he details the best methods of fixing iron chains, and securing timber-work to rocks, which we shall give in his own words.

"As nothing would stand upon the sloping surface of the rock without artificial means to stay it, Mr. Rudyerd judiciously concluded, that if the rock were reduced to level bearings, the heavy bodies to be placed upon it, would then have no tendency to slide; and this would be the case, even though but imperfectly executed; for the sliding tendency being taken away from those parts that were reduced to a level, the whole would be much more securely retained by the iron bolts or branches, than if, for the retention of the whole, they had depended entirely upon the iron-work; as manifestly appears to have been the case with the building of Mr. Winstanley. According to Mr. Rudyerd's print, the inclined surface of the rock was intended to have been reduced to a set of regular steps, which would have been attended with the same good effect, as if the whole could have been reduced to one level; but in reality, from the hardness of the rock, the shortness and uncertainty of the intervals in which this part of the work must have been performed; and the great tendency of the laminæ whereof the rock is composed to rise in spawls, according to the inclined surface, when worked upon by tools, urged with sufficient force to make an impression; this part of the work, that is, the stepping of the rock, had been but imperfectly performed, though in a degree that sufficed.

"The holes made to receive the iron branches, appear to have been drilled into the rock by jumpers, making holes of about 2¼ inches diameter; the extremities of the two holes forming the breadth for the branch, at the surface of the rock, were about 7½ inches; and these holes were directed so that at their bottoms they should be separated somewhat better than an inch more, that is, so as to be full 8½ inches. In the intermediate space, a third hole was bored between the two former; and then if the three holes were broken into one, by square-faced pummels, this would make the holes sufficiently smooth and regular. By this means he obtained holes of a dove-tail shape, being 2¼ inches wide, 7½ broad at top, 8½ at bottom, and 15 and 16 inches deep; and as these could not be made all alike, every branch was forged to fit its respective hole. The main pieces of

each branch, were about $4\frac{1}{2}$ inches broad at the surface of the rock, and $6\frac{1}{2}$ at the bottom; and this being first put down into the hole, the space left for a key would be 3 inches at top, and 2 inches at bottom, which would admit it to be driven in so as to render the whole firm, and the main branch fixed like a dove-tail or lewis.

"The holes being each finished, and fitted with their respective branches, and cleared of water, a considerable quantity of melted tallow was poured into each hole: the branch and key being then heated to about a blue heat, and put down into the tallow, and the key firmly driven, all the space unfilled by the iron, would become full of tallow, and the overplus made to run over: when this was done, all remaining hot, a quantity of coarse pewter, being made red-hot in a ladle, and run into the chinks, as being the heaviest body, would drive out the superfluous melted tallow: and so effectually had this operation succeeded, that in those branches which were cut out in 1756, and had remained fast, the whole cavity had continued so thoroughly full, that not only the pewter, but even, in general, the tallow, remained apparently fresh: and when the pewter was melted from the irons, the scale appeared upon the iron, as if it had come from the smith's forge, without the least rust upon it.

"All the iron branches, which are shown, as I found them, in Plate I, having been fixed in the manner above-mentioned, they next proceeded to lay a course of squared oak balks, lengthwise upon the lowest step, and of a size to reach up to the level of the step above. Then a set of short balks were laid crosswise of the former, and upon the next step compoundedly, so as to make good up to the surface of the third step. The third stratum was therefore again laid lengthwise, and the fourth crosswise, &c., till a basement of solid wood was raised, two complete courses higher than the highest part of the rock; the whole being fitted together, and to the rock, as close as possible, and the balks, in all their intersections with each other, trenailed together. They were also fitted to the iron branches where they happened to fall in; for the branches do not seem to have been placed with any complete regularity or order, but rather where the strength and firmness of the rock pointed out the properest places for fixing them; they were, however, to appearance disposed so as to form a double circle, one about a foot within the circumference of the basement, and the other about three feet within the former; besides which, there were two large branches fixed near the centre, for taking hold of the two sides of a large upright piece of timber, which was called *the mast;* by which two branches it was strongly fixed down; and being set perpendicular, it served as a centre for guiding all the rest of the succeeding work.

"The branches were perforated, in their respective upper parts, some with three, and some with four holes; so that, in every pair (collectively called *a branch*) there would be at a medium seven holes; and as there were at least thirty-six original branches, there would be 252 holes, which were about seven-eighths of an inch in diameter; and, consequently, were capable of receiving as many large-bearded spikes, or jag-bolts, which being driven through the branches into the solid timber, would undoubtedly hold the whole mass firmly down; and the great multiplicity of trenails in the intersections, would confine all the strata closely and compactly together.

"I cannot omit here to remark, that though the instrument we now call *the lewis*, is of an old date, yet, so far as appears, this particular application of that idea, which Mr. Rudyerd employed in fixing his iron branches firmly to the rock, was made use of for the first time in this work: for though Mr. Winstanley mentions his having made twelve holes, and fixed twelve great irons in the rock, in his first year's work, yet he gives no intimation of any particular mode of fixing them, but the common way with lead; and the stump of one of the great irons of Mr. Winstanley's, that was cut out in the course of the work of the summer of 1756, was fixed in that manner; but we remarked, that the low end of this bar or stanchion, was a little club-ended, and that the hole was somewhat under-cut; so that, when the lead was poured in, the whole together would make a sort of dovetail engraftment: however, when these irons, by great agitations, became loose, and the lead yielded in a certain degree, they would be liable to be drawn out; as the orifice by which they entered must have been large enough to receive the iron club. Mr. Rudyerd's method, therefore, of keying and securing, must be considered as a material accession to the practical part of engineery; as it furnishes a secure method of fixing ring-bolts and eye-bolts, stanchions, &c., not only into rocks of any known hardness; but into piers, moles, &c., that have already been constructed, for the safe mooring of ships; or fixing additional works, whether of stone or wood.

"In this way, by building *stratum super stratum*, of solid squared oak timber, which was of the best quality, Mr. Rudyerd was enabled to make a solid basement of what height he thought proper: but in addition to the above methods, he judiciously laid hold of the great principle of engineery, that weight is the most naturally and effectually resisted by weight. He considered, that all his joints being pervious to water, and that though a great part of the ground-joint of the whole mass was in contact with the rock, yet many parts of it could not be accurately so; and therefore, that whatever parts of the ground-joint were not in perfect contact, so as to exclude the water therefrom, though the separation was only by the thickness of a piece of post-paper, yet if capable of receiving water in a fluid state, the action of a wave upon it edgewise, would, upon the principles of hydrostatics, produce an equal effect towards lifting it upwards, as if it acted immediately upon so much area of the bottom as was not in close contact.

"The more effectually therefore to counteract every tendency of the seas to move the building in any direction, he determined to interpose strata of Cornish moor-stone between those of wood; and accordingly having raised his foundation solid, two courses above the top of the rock, he then put on five courses, of one foot thick each, of the moor-stone. These courses were as well jointed as the workmen of the country could do it, to introduce as much weight as possible into the space to contain them: they were, however, laid without any cement; but it appears that iron cramps were used, to retain the stones of each course together, and also upright ones to confine down the outside stones.

"When five feet of moor-stone were laid on, which, according to the dimensions, would weigh 120 tons; he then interposed a couple of courses of solid timber, as before; the use of which was plainly for the more effectual and ready fastening of the outside uprights to the solid, by means of jag-bolts, or screw-bolts; and that these bolts might the more effectually hold in the wood, in every part of the circle (which could not be the case with timbers lying parallel to each other, because in two points of the circle, opposite to each other, the timbers would present their ends towards the bolt) he encompassed those two courses with circular, or what are technically called *compass timbers*, properly scarfed together, and breaking joint one course upon the other. We must not, however, suppose, that these courses were composed wholly of circular timbers to the centre, but that the circles of compass timbers on the outside, were filled up with parallel pieces within; and that the compass

timbers were, in the most favourable points, jag-bolted to the interior parallel pieces.

"The two uppermost courses, after clearing the rock, and before the five moor-stone courses came on, were furnished with compass timbers, as well as some others below.

"The two courses of wood above the moor-stone courses terminated the entire solid of the basement; for a well-hole was begun to be left upon these courses for stairs in the centre, of 6 feet 9 inches in the square; and hereupon was fixed the entry door, or rather, one course lower, making a step up, just within the door; in consequence of this, the entire solid terminated about 9 feet above the higher side of the base, and 19 feet above the lower side thereof.

"In Mr. Winstanley's house, the entry was from the rock into an internal staircase, formed in the casing upon the south-east side; he therefore needed only a few external steps. But Mr. Rudyerd's entry door, being full eight feet above the highest part of the rock, would consequently need a ladder. This he made of iron, of great strength; and being open, whenever the seas broke upon this side of the house, they readily found their passage through, without making any violent agitation upon it.

"The two compass courses terminating the entire solid, having been established, as already mentioned, he again proceeded with five moor-stone courses; nearly the same as the former; allowing for the necessary difference resulting from there now being a central well-hole for the stairs, and a passage from the entry door, as described, to the well-hole: this passage was 2 feet 11 inches wide, and, as it appears, took up the whole height of the five courses. The weight of these five courses, according to the dimensions, amounted to 86 tons.

"He then again proceeded with two compass courses, covering the door-head and passage, so as now to leave no other vacuity than the well-hole; and upon these he laid four moor-stone courses, the weight of which amounted to sixty-seven tons. He then proceeded with two compass courses, and after that, with beds of timber, cross and cross, and compass courses interposing; and, last of all, with one compass course, upon which he laid a floor over all, of oak plank three inches thick, which made the floor of the store-room.

"The height of this floor above the bottom of the well, was near 18 feet; above the foot of the mast, 33 feet; above the rock on the higher side, 27 feet; and above the foot of the building on the lower side, 37 feet. In all this height, no cavity of any kind was intended for any purpose of depositing stores, &c. From the rock to the bottom of the well, all was solid, as we have shown; but as the building increased in height, and consequently was more out of the heavy stroke of the sea, a less degree of strength and solidity would be equivalent to the former, and therefore admit of the convenience of a staircase within the building, with a passage into it: which last, being made upon the east side, would be withdrawn from the heavy shock of the seas from the south-west quarter, and the rock being there highest, the ascent by the iron stair upon the outside, would be the least; the whole therefore, to the height of the store-room floor, as above-mentioned, having been made with all possible solidity, was denominated *the solid.*

"The height of Mr. Rudyerd's store-room floor was fixed as high as the floor of Mr. Winstanley's state-room, which was over his store-room; and as many were doubtless still living who had seen and examined Mr. Winstanley's light-house, during the four years that it stood in a finished state; and as in that time there would be an opportunity of knowing, from experience, to what height the unbroken water of the waves mounted in bad weather, we may very well suppose that Mr. Rudyerd regulated the height of his solid from that information.

"We have already seen, that the two compass courses of wood, which capped the first bed of moor-stone, and terminated the entire solid, were forcibly screwed down by ten large iron bars, or bolts, to the beds of timber below the moor-stone, and these by the trenails and branches to the rock. We must suppose this precaution to have been taken to prevent any derangement from the heavy strokes of the sea in storms and hard gales, which were liable to happen in the very finest part of the season, before there was any proper opportunity of connecting the upper part of the work with the lower, by means of the upright timbers that were to form the outside case; because, till the work was brought to that height, there could be no proper means of beginning to fix them; and as we do not find any traces or mention of binding the upper courses with the lower, after the staircase was set forward, we must suppose that the outside casing had been then begun from the rock, and carried on progressively, so as to become a bond of the upright kind; for, all such timbers as were high enough having been screwed fast to the compass courses, would be thereby secured to the lower courses; otherwise, from what I have myself experienced of the situation, I should have expected, that whenever the two courses of compass timber were put upon the second bed of moor-stone, if a hard gale should have come on at south-west, it would not only have lifted up and carried away the timber beds, but possibly would have deranged the moor-stone courses, notwithstanding the upright cramps to the outside stones.

"The solid being in this manner completed, the upper part of the building, comprehending four rooms, one above another, was chiefly formed by the outside upright timbers; having one kirb or circle of compass timber at each floor, to which the upright timbers were screwed and connected, and upon which the floor timbers were rested. The uprights were also jag-bolted and trenailed to one another, and, in this manner, the work was carried on to the height of 34 feet above the store-room floor, and there terminated by a planking of three inches thick, which composed the roof of the main column, as well as served for the floor of the lantern, and of the balcony round it.

"Thus the main column of this building consisted of one simple figure, being an elegant frustum of a cone, unbroken by any projecting ornament, or anything whereon the violence of the storms could lay hold; being, exclusive of its sloping foundation, 22 feet 8 inches upon its largest circular base, 61 feet high above that circular base, and 14 feet 3 inches in diameter at the top; so that the circular base was somewhat greater than one-third of the total height, and the diameter at top was somewhat less than two-thirds of the base at the greatest circle.

"The junction of the upright timbers upon each other was by means of *scarfs*, as they are technically called in ship-building and carpentry; that is, the joining of timbers end to end by over-lapping. The timbers were of different lengths, from 10 to 20 feet, and so suited, that no two joinings or scarfs of the uprights might fall together. The number of uprights composing the circle was the same from top to bottom; and their number being seventy-one, the breadth at the bottom would be 1 foot nearly; their thickness there was 9 inches; and, as they diminished in breadth towards the top, they also diminished in thickness. The whole of the outside seams were well caulked with oakum, in the same manner as in ships, and the whole payed over with pitch; consequently, upon a near view, the seams running straight from top to bottom in some measure resembled

the flutings of columns; which, in so simple a figure, could not fail to catch the attention of the beholder, and prove an agreeable engagement of the eye.

"The whole of the building was, indeed, a piece of shipwrightry: for it is plain, from the preceding account, that the interposed beds of moor-stone had nothing to do with the frame of the building, it being entire and complete exclusive thereof: the beds of moor-stone could therefore only be considered in the nature of ballast, and amounted, from what has been before stated, in the whole, to the weight of above two hundred and seventy tons.

"All the windows, shutters, and doors, were composed of double plank, cross and cross, and clinked together; which falling into a rebate when shut, their outside formed a part of the general surface, like the port-holes in a ship's side; without making any unevenness or projection in the surface. There were, however, two projecting parts terminating this frustrum; one at the top, and the other at the joining with the rock; the utility of which seems to render them indispensable. They had each a projection of about 9 inches. The top projection, which is in the nature of a cornice, consisted of a simple bevel, and the use of it was very great; for in times of storms and hard gales of wind, when, according to the accounts of Mr. Winstanley's building, the broken sea rises to a far greater height than the whole structure, it would be likely to break the windows of the lantern, unless there was something to throw it off, as their use does not admit of any defence by shutters. Therefore Mr. Rudyerd applied this simple cornice, judging it sufficient to have the effect of throwing off the sea in times of storms; and yet not so much projection as that the sea, at the height of 71 feet above the foot of the building, could have power enough to derange it.

"The bottom projection, which has been called *the kant*, and which fills up the angle formed between the uprights and the sloping surface of the rock, so as to guard the foot of the uprights from that violence of action which the waves naturally exert when driven into a corner, was certainly a very useful application; but I am inclined to think it was not there upon the first completion.

"Upon the flat room of the main column, as a platform, Mr. Rudyerd fixed his lantern, which was an octagon of 10 feet 6 inches diameter externally. The mean height of the window-frames of the lantern above the balcony floor, was nearly 9 feet; so that the elevation of the centre of the light above the highest side of the base was 70 feet; that is, lower than the centre of Mr. Winstanley's second lantern by 7 feet; but higher than that of his first by 24 feet. The width of Mr. Rudyerd's lantern was, however, nearly the same as that of Mr. Winstanley's second; but, instead of the towering ornaments of iron work, and a vane that rose above the top of the cupola no less than 21 feet, Mr. Rudyerd judiciously contented himself with finishing his building with a round ball, of 2 feet 3 inches diameter, which terminated at 3 feet above the top of his cupola. The whole height of Mr. Rudyerd's lantern, including the ball, was no more than 21 feet above his balcony floor; whereas that of Mr. Winstanley's including the iron ornaments, was above 40.

"The whole height, then, of Mr. Rudyerd's light-house, from the lowest side to the top of the ball, was 92 feet, upon a base of 23 feet 4 inches, taken at a medium between the highest and lowest part of the rock that it covered.

"I have endeavoured to describe this building with all possible minuteness, because it affords a great and very useful lesson to future engineers. We are sure that a building such as Mr. Winstanley's was not capable of resisting the utmost fury of the sea, because, in four years after its completion, it was totally demolished thereby: but Mr. Rudyerd's building having sustained the repeated attacks of that element, in all its fury, for upwards of forty-six years after its completion; and then being destroyed, not by water, but by fire; we must conclude, it was of a construction capable of withstanding the greatest violence of the sea in that situation. And by withstanding it there, this light-house proves the practicability of a similar erection in any like exposure in the known world.

"I have seen a paper in the hands of one of the present proprietors, upon which were put down the quantities of materials said to have been expended in the construction of this building: viz., 500 tons of stone, 1,200 tons of timber, 80 tons of iron, and 35 tons of lead; and of trenails, screws, and rack-bolts, 2,500 each."

Mr. Smeaton then proceeds to detail the means by which the erection of the new lighthouse fell into his hands, his several interviews with the proprietors, and various other preliminary occurrences, among which the following remarks on the difference in structure of stone and wood, and on the bond of the stones to the rock and to each other, are particularly worthy of notice.

"In reflecting upon the late structure, it appeared most evidently, that had it not been for the moor-stone courses, inlaid into the frame of the building, and acting therein like the ballast of a ship, it had long ago been overset, notwithstanding all the branches and iron-work contrived to retain it: and that, in reality, the violent agitation, rocking, or vibration, which the late building was described to be subject to, must have been owing to the narrowness of the base on which it rested; and which, the quantity of vibration it had been constantly subject to, had rendered, in regard to its seat, in some degree rounding, like the rockers of a cradle. It seemed therefore a primary point of improvement, to procure, if possible, an enlargement of the base, which, from the models before me, appeared to be practicable. It also seemed equally desirable, not to increase the size of the present building in its waist; by which I mean that part of the building between the top of the rock and the top of the solid. If therefore I still kept strictly to the conical form, a necessary consequence would be, that the diameter of every part being proportionably increased by an enlargement of the base, the action of the sea upon the building would be greater in the same proportion; but as the strength increases in proportion to the increased weight of the materials, the total absolute strength to resist that action of the sea, would be greater by a proportional enlargement of every part, but would require a greater quantity of materials; on the other hand, if we could enlarge the base, and at the same time rather diminish than increase the size of the waist and upper works; as great a strength and stiffness would arise from a larger base, accompanied with a less resistance to the acting power, though consisting of a less quantity of materials, as if a similar conical figure had been preserved.

"On this occasion, the natural figure of the waist or bole of a large spreading oak, presented itself to my imagination. Let us for a moment consider this tree: suppose at 12 or 15 feet above its base, it branches out in every direction, and forms a large bushy top, as we often observe. This top, when full of leaves, is subject to a very great impulse from the agitation of violent winds; yet, partly by its elasticity, and partly by the natural strength arising from its figure, it resists them all, even for ages, till the gradual decay of the material diminishes the coherence of the parts, and they suffer piecemeal by the violence; but it is very rare that we hear of such a tree being torn up by the roots. Let us now consider its par

ticular figure.—Connected with its roots, which lie hid below ground, it rises from the surface thereof with a large swelling base, which at the height of one diameter is generally reduced by an elegant curve, concave to the eye, to a diameter less by at least one-third, and sometimes to half of its original base. From thence its taper diminishing more slowly, its sides, by degrees, come into a perpendicular, and for some height form a cylinder. After that, a preparation of more circumference becomes necessary, for the strong insertion and establishment of the principal boughs, which produces a swelling of its diameter. Now, we can hardly doubt but that every section of the tree is nearly of an equal strength in proportion to what it has to resist: and were we to lop off its principal boughs, and expose it in that state to a rapid current of water, we should find it as much capable of resisting the action of the heavier fluid, when divested of the greatest part of its clothing, as it was that of the lighter, when all its spreading ornaments were exposed to the fury of the wind: and hence we may derive an idea of what the proper shape of a column of the greatest stability ought to be, to resist the action of external violence, when the quantity of matter is given whereof it is to be composed.

"In *Plate* V. *Figure* 1, is a sketch, representing the idea which I formed of this subject. It is farther observable, in the insertions of the boughs of trees into the bole, or of the branches into the boughs, (which is generally at an oblique angle) that those insertions are made by a swelling curve, of the same nature as that wherewith the tree rises out of the ground; and that the greatest rake or sweep of this curve is that which fills up the obtuse angle; while the acute angle is filled up with a much quicker curve, or sweep of a less radius: and *Figure* 2, of the same Plate, represents my conception of this matter. In this view of the subject, I immediately rough-turned a piece of wood, with a small degree of tapering above; and leaving matter enough below, I fitted it to the oblique surface of a block of wood, somewhat resembling the sloping surface of the Eddystone rock; and soon found, that by reconciling curves, I could adopt every part of the base upon the rock to the regularly turned tapering body, and so as to make a figure not ungraceful; and at the same time carrying the idea of great firmness aud solidity.

"The next thing was to consider how the blocks of stone could be bonded to the rock, and to one another, in so firm a manner, as that, not only the whole together, but every individual piece, when connected with what preceded, should be proof against the greatest violence of the sea.

"Cramping, as generally performed, amounts to no more than a bond upon the upper surface of a course of stone, without having any direct power to hold a stone down, in case of its being lifted upward by an action greater than its own weight; as might be expected frequently to happen at the Eddystone, whenever the mortar of the ground-bed it was set upon was washed out of the joint, when attacked by the sea before it had time to harden; and though upright cramps, to confine the stones down to the course below, might in some degree answer this end, yet, as this must be done to each individual stone, the quantity of iron, and the great trouble and loss of time that would necessarily attend this method, would in reality render it impracticable; for it appeared, that Mr. Winstanley had found the fixing twelve great irons, and Mr. Rudyerd thirty-five, attended with such a consumption of time (which arose, in a great measure, from the difficulty of getting and keeping the holes dry, so as to admit of the pouring in of melted lead) that any method which required still much more, in putting the work together upon the rock, would inevitably, and to a very great degree, procrastinate the completion of the building. It therefore seemed of the utmost consequence to avoid this, even by any quantity of time and moderate expense, that might be necessary for its performance on shore; provided it prevented hinderance of business upon the rock; because of time upon the rock, there was likely to be a great scarcity, but on the shore a very sufficient plenty. This made me turn my thoughts to what could be done in the way of dovetailing. In speaking however, of this as a term of art, I must observe, that it had been principally applied to works of carpentry; its application in the masonry way had been but very slight and sparing; for in regard to the small pieces of stone that had been let in with a double dovetail, across the joint of larger pieces, and generally to save iron, it was a kind of work even more objectionable than cramping; for though it would not require melted lead, yet being only a superficial bond, and consisting of far more brittle materials than iron, it was not likely to answer our end at all. Somewhat more to my purpose, I had occasionally observed, in many places in the streets of London, that, in fixing the kirbs of the walking-paths, the long pieces, or stretchers, were retained between two headers, or bond pieces; whose heads being cut dovetail-wise, adapted themselves to, and confined in, the strechers; which expedient, though chiefly intended to save iron and lead, nevertheless appeared to me capable of more firmness than any superficial fastening could be; as the tye was as good at the bottom as at the top, which was the very thing I wanted; and therefore if the tail of the header was made to have an adequate bond with the interior parts, the work would in itself be perfect. What I mean will be rendered obvious by the inspection of *Figure* 3, in *Plate* V. Something of this kind I also remembered to have seen in Belidor's description of the stone floor of the great sluice at Cherbourg, where the tails of the upright headers are cut into dovetails, for their insertion into the mass of rough masonry below. From these beginnings I was readily led to think, that if the blocks themselves were, both inside and out, all formed into large dovetails, they might be managed so as mutually to lock one another together; being primarily engrafted into the rock: and in the round and entire courses, above the top of the rock, they might all proceed from, and be locked to, one large centre stone. After some trials in the rough, I produced a complete design, of which *Figure* 5, *Plate* V., is the exact copy; the dotted lines representing the course next above or below, which in the original was drawn from the same centre, on the other side of the paper; so that looking on each side separately, each course was seen distinctly; or, looking through the paper, the relation of the two courses, showing how they mutually broke joint upon one another, was clearly pointed out: and this method of representation was pursued throughout; but not being practicable in copper-plate work, I am under the necessity of introducing the method by dotted lines, though attended with some degree of confusion of the main design.

"It is obvious, that in this method of dovetailing, while the slope of the rock was making good; by cutting the steps (formed by Mr. Rudyerd) also into dovetails, it might be said, that the foundation-stones of every course were engrafted into, or rather rooted in, the rock; which would not only keep all the stones in one course together, but prevent the courses themselves (as one stone) from moving or sliding upon each other. But after losing hold of the rock, by getting above it; then, though every stone in the same course would be bonded in the strongest manner with every other, and might be considered as consisting of a single stone, which would weigh a considerable number of tons, and would be farther retained to the floor below by the cement, so that, when completed, the sea would have no action upon it but

edgeways; yet, as a force, if sufficiently great, might move it, notwithstanding its weight, and the small hold of the sea upon it, and break the cement before time had given it that hardness which it might be expected to acquire afterwards; I had formed more expedients than one for fixing the courses to one another, so as absolutely to prevent their shifting; but I shall not trouble my reader with a recital of those expedients at present, as they will more properly come in along with the reasons of my choice, in the detail of the actual proceedings."

Mr. Smeaton made his first voyage to the Eddystone on the 2d of April, 1756, but was prevented from landing by the weather; but on the 5th of the same month he was more successful, and staid upon the rock about two hours and a half, during which time he observed, "such traces of the situations of the irons fixed by Mr. Winstanley, as that it would not be difficult to make out his plan, and the position of the edifice; from whence it appeared very probable that Mr. Winstanley's building was overset all together; and that it had torn up a portion of the rock itself with it, as far as the irons had been fastened in it." He also "perceived that Mr. Rudyerd's iron branches, as then called, were much smaller and shorter than he had described them to be at the bottom of his print; that many of them were loose, and some broken and bent: and that, in regard to the steps, described to be cut upon the rock, there were only five of them, of which the traces were remaining: so that there was but one flat or tread of a step above the centre of the house; and the upper part of the surface of the rock above that, was a sloping plain, as it had been at first. Three steps, of the five now remaining, seemed to have been but faintly cut, and the uppermost but one was so imperfect, that he supposed a large spawl or splinter had come from it; and this appeared the more probable, as the uppermost step was so shaken, that another large spawl might have been easily raised from it, by a slight action of a wedge. Above the uppermost step the rock seemed to be of a softer nature, was cracked in many places, and probably had received some damage from the fire. None of the steps appeared to have been cut with much regularity, either as to level or square; but to have all the marks of hurry upon them. In the centre of the house a slight footing was cut for the mast, suitable to a square of 18 inches, with large iron branches, answerable to two of its sides, and a small hole bored in the centre, of about 1¼ inch diameter, being 6 inches deep. By consulting Plate I., many of the above matters will be made apparent to the eye.

"I then," says Mr. Smeaton, "proceeded to try the degree in which the rock was workable, and found that from a flat surface, indifferently taken, I could, with a pick, sink a hollow at the rate of five cubic inches per minute; and could cut or drill a hole with a jumper of 1¼ inch diameter, at the rate of one inch deep in five minutes. I also tried a method of forcing two holes into one, by a square flat-faced bruiser, or pummel; so that, if there should be occasion, I might be able to make a continued groove; or let in an iron branch, in the manner of Mr. Rudyerd, and I had the satisfaction to find that the whole succeeded to my wishes."

In the choice of materials, Mr. Smeaton was determined in favour of moor-stone or granite, for the outside work, and Portland stone for the inside. The latter was not eligible for the outer surface, on account of its liability to be destroyed by a marine insect; and the moor-stone was too hard and expensive in the working to admit of its being used throughout the building.

By the 15th of May, Mr. Smeaton had made ten voyages of observation to the Eddystone, and then returned to London, where having settled with the proprietors, he received his commission to proceed on the work. He then went back to Plymouth, and, on the 3d of August, landed with the first company of workmen on the rock, where he began to fix the centre and lines of the work. After describing the difficulties under which he laboured from the uncertainty of the weather, and the necessity in which the workmen were placed, of returning to shore every tide, till a vessel fit for their reception could be properly moored off the rock, Mr. S. observes upon his preference of the use of picks and wedges for operating upon the rock, that "it might seem, at first sight, that a greater dispatch would have been by the use of gunpowder, in blasting the rock, in the same manner as is usual in mines, and in procuring limestone from the marble rocks in the neighbourhood of Plymouth: but though this is a very ready method of working hard and close rocks, in proportion to the dispatch that could be made by picks and wedges; yet, as a rock always yields to gunpowder in the weakest part, and it is not always easy to know which part is weakest; it might often have happened, if that method had been pursued, that, instead of forming a dovetail recess, such as was required, the very points of confinement would have been lost. Besides, the great and sudden concussion of gunpowder might possibly loosen some parts that it was more suitable to the general scheme should remain fast. For these reasons, I had previously determined to make no use of gunpowder for this purpose.

"On the 7th of September," says Mr. Smeaton, "I sent to Portland the draughts for the six foundation courses, that were to be employed in bringing the rock to a level; which, with the draughts for eight that I had before dispatched, completed the order for the whole quantity of Portland stone to be used in the solid up to the entry door; being all that we could expect to set in place the next season. The rock was not indeed yet ready for completing the exact moulds for those stones that were to fit into the dovetails made in it; but, by ordering the stones large enough, and being scappelled something near their proper form, it would prevent loss of time in waiting to get the true figure from the rock, as well as unnecessary waste.

"Nothing happened to prevent the companies from working every tide from the 27th of August, till the 14th of September, in which time they had worked one hundred and seventy-seven hours upon the rock. In this interval, having procured a carpenter to be applied to that purpose, I began to make the moulds for the exact cutting of the stones to their intended shapes. This was done by laying down, in chalk-lines upon the floor of a chamber, the proposed size and figure of each stone, being a portion of the plan at large of the intended course; and the carpenter having prepared a quantity of battens, or slips of deal board, about three inches broad, and one inch thick, shot straight upon the edges by a plane; those battens being cut to lengths, and their edges adapted to the lines upon the floor, and properly fitted together, became the exact representatives of the pieces of stone whose figure was to be marked from them, when their beds were wrought to the intended parallel distance.

"It is obvious that there was no necessity for making moulds for a whole course after the work became regular; as was the seventh course, after the six foundation courses brought the rock to a level; it was sufficient to make one mould to each circle of stones, beginning with the centre stone; but as the six foundation courses were adapted to the particular irregularities of the rock, and consequently could not be strictly regular, it was necessary that a separate mould should be made for every separate stone composing that part of the work.

"During this interval, I visited the rock, and on arriving

there the 8th of September, was informed by Mr. Jessop, that the preceding evening, there being a very strong tide, and no wind, a West-Indiaman, homeward bound, and a man-of-war's tender, were in great danger of driving upon the north-east rock; but that he timely perceiving their danger, though they themselves were not aware of it, ordered out the seamen and hands, who towed them off.

"On this visit, I staid two days; for as the working company had begun to take down the upper part of the rock, it was necessary to concert, and put in practice, the proper means of doing that, without damage to what was destined to remain. I have already mentioned my resolution of not using gunpowder; yet it was necessary, for the sake of dispatch, to employ some means more expeditious than the slow way of crumbling off the matter by the blunt points of picks. It has been already noticed, that the laminæ composing the rock were parallel to the inclined surface; and it was very probable that the chasm into which Mr. Winstanley's chain had been so fast jambed, that it never could be disengaged, extended farther into the rock than the visible disunion of the parts: this made me resolve to try a method sometimes used in this country, for the division of hard stones, called *the key and feather*, in order to cross-cut this upper stratum of the rock. The construction and operation of the key and feather is as follows:—A right line is marked upon the surface of the rock or stone to be cut, in the direction in which it is intended to be divided. Holes are then drilled by a jumper, at the distance of six or eight inches, and about one inch and a quarter in diameter, to the depth of about eight or nine inches; the distances, however, of the holes, and their diameters, as well as their depth, are to be greater or less, according to the strength of the stone, in the estimation of the artist directing the work. The above dimensions were what we used on this occasion. The key is a long tapering wedge, of somewhat less breadth than the diameter of the holes, and so as to go easily into them; the length being three or four inches more than the depth of the holes. The feathers are pieces of iron, also of a wedge-like shape; the side to be applied to the key being flat, but the other side a segment of a circle, answerable to that of the holes; so that the two flat sides of two feathers being applied to the two flat sides of the key, and the thick end of the feathers to the thin end of the key, they all together compose a cylindric, or rather oval kind of body; which in this position of parts is too big to go into the holes by at least one-eighth of an inch; that is, in the direction of a diameter passing through the three parts; but, in the other direction, is no broader than to go with ease into the holes. A key and a pair of feathers is made use of in each hole; and the feathers being first dropped in, with the thick ends downward, the keys are then entered between them; the flat sides of all the keys and the feathers being set parallel to that line in which the holes are disposed; the keys are then driven by a sledge-hammer, proceeding from one to another, and being forced gradually, as in splitting of moor-stone, the strongest stones are unable to resist their joint effort; and the stone is split according to the direction of the original line, as effectually, and much more regularly and certainly, than could be done with gunpowder, and without any concussion of the parts. Had our rock been entirely solid, this way of working might not have been applicable, on account of the crack's going too deep; but here, when it arrived at the joint where the chain was lodged, the split part became entirely disengaged from the rest; and in this way we were enabled to bring off the quantity of several cubic feet at a time: and thus the chain was released, after a confinement of above fifty years. The impossibility of disengaging it before now appeared very evident; for the pressure had been so great by the rock's closing upon it, as before suggested, that the links in their intersections were pressed into each other, as completely as if they had been made of lead; though the bolt-iron composing thec hain had been at least five-eighths of an inch in diameter.

"On Thursday, the 16th, I again went off to the rock, and found the work in the following situation. The lowest new step (the most difficult to work upon, because the lowest) with its dovetails quite completed. The second step rough-bedded, and all its dovetails scappelled out. The third step (being the lowest in Mr. Rudyerd's work) smooth-bedded, and all the dovetails roughed out. The fourth in the like state. The fifth rough-bedded, and dovetails scappelled out: and the sixth smooth-bedded, and all the dovetails roughed out. Lastly, the top of the rock, the greatest part of the bulk whereof had been previously taken down by the key-and-feather method, as low as it could be done with propriety, was now to be reduced to a level with the upper surface of the sixth step; the top of that step being necessarily to form a part of the bed for the seventh, or first regular course; so that what now remained, was to bring the top of the rock to a regular floor by picks: and from what now appeared, (as all the upper parts, that had been damaged by the fire, were cut off,) the new building was likely to rest upon a basis even more solid than the former had done.

"On Thursday, the 30th, I traced the outlines upon the upper part of the rock for the border of the seventh course, all within which was to be sunk to the level of the top of the sixth, and all without to be left standing, as a border for defence of the ground-joint of the work with the rock; and measuring the height of the top step above the bed of the first, I found it to be eight feet four inches: which would now be the difference of level between the west or lowest side of the new building, and the east or highest."

The setting in of the equinoctial winds prevented much farther progress in the work for this season; but on the 7th of November, the weather being somewhat moderate, Mr. Smeaton went off in the Eddystone boat, with battens, and the carpenter, to mould off the dovetails from the rock, when he found "four or five of the dovetails in the upper step wanting some amendment, that would employ as many men at each, for about four or five hours. The greatest part of the top of the rock was now brought to a regular floor, but some part of the north-east side wanted bringing down to a level." And here the operations for the year ended; for, on the 15th of the month, the workmen left the rock, having been able to make only thirty-eight hours and a half since the 2nd of October.

Mr. Smeaton occupies the interval between this period and the next working season with describing the regulations of his mason's yard, the size of the stones, &c., among which the following remarks may be useful to the reader.

"From the beginning I always laid it down as a fundamental maxim, that on account of the precariousness of weather to suit our purposes, (and without its being favourable, I think it has already sufficiently appeared, that nothing is to be done upon the Eddystone,) if we could save one hour's work upon the rock, by that of a week in our work-yard, this would always prove a valuable purchase; and that therefore everything ought to be done by way of preparation, which could tend to the putting our work together with expedition and certainty, in the ultimate fixing of it in its proper place; and for this purpose, it was necessary to make use of as large and heavy pieces of stone as, in such a situation as the Eddystone, were likely to be capable of being managed without running too great a risk.

"The common run of modern buildings, even of the largest size, are composed of pieces in general not exceeding five or six hundred-weight, except where columns, architraves, cornices, and other parts are to be formed, that indispensably require large single pieces; because stones of this size and bulk are capable of being handled without the use of tackles, or purchases, unless where they are to be raised perpendicularly: yet it appeared to me, that this choice of general magnitude resulted only from the workmen's not having commonly attained all that expertness in the management of the mechanic powers that they might have; in consequence of which, they avoid, wherever they can, the necessity of employing them. This arises not from the real nature of the thing, when properly understood; for a stone of a ton weight is, when hoisted by a proper tackle, and power of labourers, as soon and as easily set in its place, as one of a quarter of that weight; and, in reality, needs much less hewing than is necessary for the preparation of four stones to fill up the same space; nor need this reasoning stop at stones of a ton weight, but it might proceed even to as large sizes as are said to be found in the ruins of Balbec, if there were not inconveniences of other kinds to set on the opposite side of the question, as well as the want of quarries in this kingdom to produce stones of that magnitude.

"The size of the stones that could be used in the Eddystone lighthouse seemed limited by the practicability of landing them upon the rock: for as nothing but small vessels, that were easily manageable, could possibly deliver their cargoes alongside of the rock, with any reasonable prospect of safety; so no small vessels could deliver very large stones, because the sudden rising and falling of the vessels in the gut amounted frequently to the difference of three or four feet, even in moderate weather, when it was very practicable for a vessel to lie there; so that in case, after a stone was raised from the floor of the vessel, her gunnel should take a swing, so as to hitch under the stone, one of such a magnitude as we are now supposing, on the vessel's rising, must infallibly sink her; and hence it appeared, that much of the safety in delivering the cargoes would depend upon having the single pieces not to exceed such weight as could be expeditiously hoisted, and got out of the way of the vessel, by a moderate number of hands, and by such sort of tackles as could be removed from the rock to the store-vessel each tide: and on a full view of the whole matter, it appeared to me very practicable to land such pieces of stone upon the rock, as in general did not much exceed a ton-weight; though occasionally particular pieces might amount to two tons.

"The general size of our building stones being thus determined upon at a ton-weight, those would have been far too heavy to be expeditiously transferred and managed, even in the work-yard, unless our machinery rendered that easy, which would otherwise be difficult, without too great an expense of labour: and as the moving and transferring the pieces of stone in the work-yard would be greatly increased in quantity, by the very mode of attaining a certainty in putting the work together upon the rock; this consideration made it still the more necessary to be able to load upon a carriage, and move the different pieces from one part of the yard to the other, with as much facility (comparatively speaking) as if they had been so many bricks: for, that we might arrive at perfect certainty in putting the work ultimately together in its place upon the rock, it did not appear to be enough, that the stones should all be hewn as exactly as possible to moulds that fitted each other; but it was farther necessary, that the stones in every course should be tried together in their real situation in respect to each other, and so exactly marked, that every stone, after the course was taken asunder, could be replaced in the identical position in which it lay upon the platform, within the fortieth part of an inch. Nor was this alone sufficient; for every course must not only be tried singly together upon the platform, and marked, but it must have the course next above it put upon it, and marked in the same manner, that every two contiguous courses might fit each other on the outside, and prevent an irregularity in the outline: and this indeed, in effect, amounted to the platforming of every course twice: so that, in this way of working, every stone must be no less than six times upon the carriage:—1st. When brought into the yard from the ship, to carry it to the place of deposition, till wanted to be worked.—2ndly. When taken up and carried to the shed to be worked.—3rdly. After being wrought. to be returned to its place of deposition.—4thly. When taken up to be carried to the platform.—5thly. When finished on the platform, to be returned to its place of deposition.—6thly. When taken up to be carried to the jetty, to be loaded on board a vessel to go to sea.

"It might, at first sight, appear superfluous to try the courses together upon each other, as the under and upper sides of all the courses were planes: and, in case the work could have been put together upon the rock in the same way that common masonry generally is done, it would have been so: that is, if we could have begun our courses by setting the outside pieces first, then it would have been very practicable to have regulated the inside pieces thereto; but as our hope of expedition depended upon certainty in every part of our progress, this required us to be in a condition to resist a storm at every step: the outside stones therefore, unconnected with the inner ones, would have scarce any fastening besides their own weight, and would be subject to the most immediate and greatest shock of the sea; and, after completing the outward circle, the inner space would be liable to become a receptacle for water: the necessity therefore of fixing the centre stone first, as least exposed to the stroke of the sea, and of having sure means of attaching all the rest to it, and to one another, rendered it indispensable that the whole of the two courses should be tried together; that if any defect appeared at the outside, by an accumulation of errors from the centre, it might be rectified upon the platform.

"The moor-stone, though very hard with respect to its component parts, yet being of a friable nature, is extremely difficult to work to an arris (or sharp corner,) or even to be preserved, when so wrought by great labour and patience: that is, with sharp tools, and small blows; it therefore soon appeared to me, that we should make very rough and coarse work of it, if the finishing of the pieces were left to the workmen of the country where produced: for, though carefully wrought there in their place, yet in loading and unloading from their carriages, and again putting on board, and unloading from the vessels, the arrises would be very subject to damage. Therefore, to have as much done in the country as possible, and to save weight in carriage (leaving the finishing part to be done at home) rough moulds were sent for each size and species of stone, which were to be worked by them to a given parallel thickness, and with length and breadth enough, when so bedded, (as it is called) to be cut round all the sides to the true figure of the finishing mould: but they were to reduce them as near the size as they could safely do it by the hammer; and, that they might not leave an unnecessary waste, they were to be paid no more for either stone or carriage, than what the mould measured upon the thickness given; and if they were wanting of substance sufficient to make the figure complete, it should be at our option to reject them when they came home."

Our author next proceeds to detail his experiments on cements; but as they constitute no part of the building process, the reader is referred to the articles CEMENT and MORTAR, where the subject is duly considered.

On the 5th of June, 1757, the operations on the rock were recommenced, and by the 10th all the preliminary matters were settled; so that "on Saturday, the 11th of June, the first course of stone was put on board the Eddystone boat, (*see Plate* III. *Figure* 1,) with all the necessary stores, tools, and utensils. We landed at eight on Sunday morning, the 12th of June, and before noon had got the first stone into its place, being that upon which the date of the year 1757 is inscribed, in deep characters; and the tide coming upon us, we secured it with chains to the old stanchions, and then quitted the rock till the evening tide, when it was fitted, bedded in mortar, trenailed down, and completely fixed; and all the outward joints coated over with plaster-of-paris, to prevent the immediate wash of the sea upon the mortar. This stone, according to its dimensions, weighed two tons and a quarter. The weather serving at intervals, it was in the evening of Monday, the 13th, that the first course, consisting of four stones, was finished; and which, as they all presented some part of their faces to the sea, were all of moor-stone.

"The next day, Tuesday the 14th, the second course (*see Plate* III. *Figure* 2,) arrived; and some of it was immediately landed, proceeded with, and in part set the same tide: the loose pieces being chained together by strong chains, made on purpose for this use, and those ultimately to the stancheons, or to lewises in the holes of the work Course I. that had already been fixed. The sea was uncommonly smooth when we got upon the rock, this evening's tide, but while we were proceeding with our work, within the space of an hour and a half, the wind sprung up at north-east, and blew so fresh, that the Weston, lying to deliver the remainder of her cargo, had some difficulty in getting out of the gut; and, had it not been for the transport buoy, to which she had a fastening by a rope, it would probably have proved impracticable to have got her out again. And we soon saw it was necessary to get everything in the best posture time and circumstances would admit, in order to quit the rock with safety to ourselves, and security to what we must necessarily leave behind us.

"The pieces that were fixed and trenailed down, were supposed to be proof against whatever might happen; but the loose pieces, and those that were simply lowered down into their dovetail recesses, were considered as needing some additional security, to prevent their being carried away by the violence of the sea. Of the thirteen pieces of which Course II. consisted, five only were landed: No. 1 was completely set; No. 2 and 3 were lowered into their places, and secured by chains; and No. 4 and 5, which lay at the top of the rock, were chained together, and also to the slide-ladder, which was very strongly lashed down to the eye-bolts, purposely fixed on the rock for that intent.

"In the evening (of June 15,) we made a short tide upon the rock, and had the satisfaction to find that no material damage had happened to anything; we therefore proceeded with our work, and completely fixed No. 2 of Course II. On the morning of Friday the 17th we again landed for a short time; and, nothwithstanding we did not meet with anything amiss on our return to the rock on Wednesday evening, after the hard gale of wind, yet this morning we found a part of the rock in the border of our work, that secured a corner of No. 3, was gone: we therefore, to secure that stone to its neighbour, applied an iron cramp, of which we had some in readiness in case of accident. We were prevented landing in the evening, by a fresh wind and rain at north-west, but landed again on Saturday morning's tide, the 18th. However, we had not been long there before a great swell arose from the south-west; and though there had been no wind apparently to occasion it, yet it came upon us so fast, that we were obliged to quit the rock before we could get our work into so satisfactory a posture of defence as I wished. It was, however, as follows: No. 1, 2, 3, 4, and 5, were completely fixed as intended; No. 6 and 7, were fitted, and lowered upon their mortar-beds; No. 8, was simply got into its place, with a weight of lead of five hundred weight upon it; which, in all such trials as had hitherto been made thereof, had lain quietly. Not having time to get the stone, No. 9, into its place, we chained it upon the top of the rock to the slide-ladder, as we had done before on Tuesday. In this condition we left the rock, having staid till we were all wet from head to foot.

"The storm continued till Tuesday morning: about noon of that day," says Mr. Smeaton, "the wind and sea having become still more moderate, I judged it practicable to row ahead against it, so as to get to the westward of the rock, and reconnoitre our damages: accordingly, taking four oars in the light yawl, it being then near low water, I observed, when the sea fell away from the rocks, (every sea then breaking bodily over it,) that No. 9, and the slide-ladder to which it was chained, were both gone; that the two pieces of moor-stone, No. 5 and 6, which had only been let down upon their mortar-beds, without farther fastening, were also gone; that No. 3 had broke its cramp, and was gone; and that the five hundred weight of lead, that had been laid upon the most projecting part of the piece, No. 8, had, by the force of the sea acting edgewise upon it, been driven to the eastward, till it was stopped by the rise of the third step, against which it seemed abutted; so that having thereby quitted the piece, No. 8, upon which it was laid, that was gone also: we therefore, as it appeared, had lost five pieces of stone; the loss of which was, in the first instance, alleviated by finding that the first course appeared so thoroughly united with the rock, that its surface began to look black, with dark-coloured moss fixing upon it, and giving it the same hue as the rock itself: also, that our shears and windlass were all standing, without the least derangement.

"I did not wait for the subsiding of the winds and seas, so as to enable us to land, and look out whether or no we could recover any of the lost pieces; I immediately made for Plymouth in the light yawl, and landed at Mill Bay, at five o'clock on Tuesday evening, the 21st; and, having collected the moulds of the stones we had lost, and chosen proper spare blocks, I set a couple of men to work upon each piece of stone, day and night, till finished. This disaster, though it furnished a few reflections, yet they were not of the unpleasant kind; for, as every part of the stonework that was completed according to its original intention, appeared to have remained fixed, it demonstrated the practicability of the method chosen; and at the same time shewed the preference of wedging to cramping, as the cramp had failed: and also the utility of trenails, as a security till the mortar was become hard.

"At four o'clock on Monday morning the 27th, the weather serving, I went out with Richardson and company, in the Eddystone boat; we got to the buss at ten, and found the Weston at the transport buoy, but could not land till the afternoon's tide, being a complete week since we had been last upon the rock. We first replaced the ladder, and afterwards proceeded, without more than usual interruptions, till the 30th in the evening, when we closed and completed the Course No. II., and began upon Course III. The execution of these two courses had taken us up from the 12th to the 30th inclusive, and though they consisted of no more than

seventeen pieces of stone in the whole, yet I found myself no ways disheartened; for, in establishing these two courses, I considered the most difficult and arduous part of the work to be already accomplished, as these two courses brought us up to the same level where my predecessor Mr. Rudyerd had begun.

"Friday, July the 1st, we were able to land. I observed, that during the last tide, the swell had washed some of the pointing out of the exterior joints, and also some of the grouting out of the upright joints; but as a heavy sea seemed likely to come on with the tide of flood, I judged it to be to no purpose to repair the cement while a violent swell continued; I therefore employed the company in cutting off the iron stancheons belonging to the former building, as they now began to be in our way, and as the hold we got of them ceased to be of use, in proportion as we got more fastening from the lewis holes of our own work.

"The weather having become more favourable, on Sunday morning, the 3d of July, I went on board, accompanied by Mr. Jessop and his party, to whom, as they had never had the opportunity of setting a stone, it behoved me to attend. We, however, not only met with a repulse this day, but could not make any farther attempt to go out till Tuesday, the 5th; and then the wind, though gentle, being contrary, had not the company on board the buss come with their two yawls and towed us thither, in all probability the day would have been spent in fruitless attempts. Our difficulty was considerably increased by the coming on of so thick a fog, that, all our efforts united, we had much ado to regain the buss. Richardson told me they had had such bad weather, that the slide-ladder had again broke its lashings and driven away; that they had, however, got all the irons cut off close to the rock; but that the last tide, though there was only a breeze at south-west, the swell was so great, and came on so suddenly, as to put them in great danger of being washed off from the top of the rock, before they could quit it.

"At two o'clock this day we landed, and Jessop's company set six pieces of stone, and effectually repaired the cement; and next day a proportionable dispatch was made, though the weather was not very mild.

"On Monday, the 11th, I again went out; Course III. consisting of twenty-five pieces, was closed on the following day, and Course IV. begun.

"Thursday, the 14th of July, the company pursued the work of Course IV.; and now, both companies being fully instructed in the method of setting the basement courses, I returned to Plymouth; from whence I proposed to visit each company as often as should seem expedient, but always once in each company's turn, if wind and weather should permit.

"Contrary winds, ground-swells, and heavy seas for several days, interrupted the regularity of our proceedings; however, taking such opportunities as we could, the Course IV., consisting of twenty-three pieces of stone, was closed in the morning's tide of the 31st of July, (*see Plate* III.); and in the evening's tide five pieces of Course V. were set. Our work went on regularly for some days together; and, visiting the work upon the 5th of August, I found the Course V. containing twenty-six pieces, closed in, (*see Plate* III.); but that by some inadvertency in proceeding with the interior part, the masons had been obliged to set two of the outside pieces so as to be farther out than they should have been by an inch each. However, as I found the work was sound and firm, I thought it better to cut off the superfluous stone from the outside, than to disturb the work by the violence that must have been used in unsetting the pieces; I therefore determined to let them stand as they were, till the cement was become so hard as to support the edges of the stone while the faces were working afresh; and which, from the mortar of our first and second course, we found was likely to be the case before the close of the season. One of the dovetails had also given way in driving a trenail, owing to a flaw in the stone; for the remedying whereof we applied a cramp.

"The 8th of August, at noon, the weather being exceeding fine, with a low neap tide, I took the opportunity of drawing a meridian line upon the platform of Course VI. the sea never going over the work during the whole tide, which was the first time it had not washed over all, since we began to build: we therefore took this favourable opportunity of carefully making good all our pointings and groutings, wherever the water had washed during the bad weather that had succeeded the last departure of the Eddystone boat; and which was the case with it, in places where it had not had time to set before a rough tide came on; but I observed, with much satisfaction, that whatever, not only of the original work, but of the repaired pointing, had once stood a rough tide without giving way, the same place never after failed. I also observed, that as in mending the pointings we had in some places made trial of Dutch tarras as well as puzzolana, interchangeably, the puzzolana, for hard service, was evidently superior to the tarras: and some particular joints had proved so difficult, that I was obliged to try other expedients; the best of which was to chop oakum very small, and beat it up along with the mortar. This was our last resource, and it never failed us.

"Upon the 11th, I again went out in the vessel that contained the remaining pieces of Course VI.: those I saw fixed; and that course, consisting of thirty-two pieces, closed in the same evening. (*See Plate* III.) This completing our six basement courses, brought our work upon the same level to which we had, the preceding season, reduced the top of the rock; and upon this, as a common base, the rest of the structure was to be raised by regular entire courses. The time this part of the work (consisting of one hundred and twenty-three pieces of stone) had taken up, was from the 12th of June to the 11th of August inclusive, being a space of sixty-one days. We now considered our greatest difficulties to be successfully surmounted, as every succeeding course had given us more and more time, as well as more and more room; and this will appear from our proceedings; for it has already been noticed, that the two first courses, consisting of nineteen pieces of stone only, had cost us seventeen days.

"Having now got the work to this desirable situation, I apprehend it will be agreeable to my reader to be more particularly acquainted with the method in which the stones were set and fixed. I have intimated, that when each separate piece, of which a course was to consist, was separately wrought, they were all to be brought to their exact places with respect to each other, upon the platform in the work yard, and so marked, that, after being numbered and taken to pieces, they could again be restored to the same relative position. This was done upon the complete circular courses by drawing lines from the centre to the circumference, passing through the middle of each set of stones; and likewise concentric circles through the middle of each tier or circle of stones, so as to indicate to the eye their relative position to each other: but to render the marks not easily delible, where those lines crossed the joints, a nick was cut and sunk into the surface of the two adjacent stones; for doing which, a piece of thin plate-iron was employed, with sand, upon the principle that stones are sawn; so that not only the sight, but feeling, could be employed in bringing them together again exactly; for the same or a similar plate being applied to the nick, the least irregularity of its position would be discoverable. In a

similar manner the stones of the base courses were marked by lines drawn parallel to the length of the steps, and others perpendicular to the same, the crossings being sawn in, as before described. There was, however, a nicety in this part of the work, that required particular attention, and that was in forming a provision for setting the four radical stones, that occupy the four radical dovetails into which each step was formed, as may be observed in the several figures of *Plate* III. Those stones were formed, from the work of the rock's being actually moulded off, and from the manner, already described, of bringing those moulds to agree after they were brought home from the rock, those stones were laid upon the platform thereby, and then marked with lines upon their own substance, in the manner just mentioned: and as the distances of each of those stones were then ascertained by gauge-rods of white fir-wood, while upon the platform; it must be expected, as each step was reduced to a level plain, as the platform was, that when laid upon the rock in their due positions and distances, by the gauge-rods, they would nearly fit the dovetails that had been cut in the rock to receive them; and where there was the least want of fitness, as might possibly happen with bodies of so rigid a nature, either the stone or the rock was cut, till each stone would come into its exact relative position, and then all the rest would follow one another by their marks, in the same manner as they had done upon the platform.

"It is necessary to be noticed, that the waist of each piece of stone had two grooves cut, from the top to the bottom of the course, of an inch in depth, and three inches in width: applicable to those grooves were prepared a number of oak wedges, somewhat less than three inches in breadth, than one inch thick at the head, nearly three-eighths thick at the point, and six inches long. The disposition of these grooves is shown in the courses of *Plate* III. where the little black parallelogram figures, placed along the lines describing the joints of the courses, represent the tops of the grooves, and their place on the right hand or left of the joint line show in which stone the groove is cut. It is also to be noted, that where the flank side of a stone was not more in length than a foot, or fourteen inches, one groove was generally deemed sufficient; but those of eighteen inches or upwards had, generally, in themselves or the adjoining stone, a couple of grooves.

"The mortar was prepared for use by being beat in a very strong wooden bucket, made for the purpose; each mortar-beater had his own bucket, which he placed upon any level part of the work, and with a kind of rammer, or wooden pestle, first beat the lime alone, about a quarter of a peck at a time, to which, when formed into a complete, but rather thin paste, with sea-water, he then gradually added the other ingredient, keeping it constantly in a degree of toughness by continuance of beating. When a stone had been fitted and ready for setting, he whose mortar had been longest in beating came first, and the rest in order: the mason took the mortar out of the bucket; and, if any was spared, he still kept on beating; if the whole was exhausted, he began upon a fresh batch. The stones were first tried, and heaved into and out of their recesses, by a light movable triangle, which being furnished with a light double tackle, the greatest number of all the pieces could be purchased by the simple application of the hand; and this made our stones to be readily manageable by such machinery as could commodiously be moved and carried backward and forward in the yawls every tide. To the first stone, and some few others, we took the great tackle, that we might hoist and lower them with certainty and ease; but there were not in the whole above a dozen stones that required it.

"The stone to be set being hung in the tackle, and its bed of mortar spread, was then lowered into its place, and beat down with a heavy wooden maul, and levelled with a spirit level: and the stone being brought accurately to its marks, it was then considered as set in its place. The business now was to retain it exactly in that position, notwithstanding the utmost violence of the sea might come upon it before the mortar was hard enough to resist it. The carpenter now dropped into each groove two of the wedges already described, one upon its head, and the other with its point downward, so that the two wedges in each groove would then lie heads and points. With a bar of iron of about two inches and a half broad, three-quarters of an inch thick, and two feet and a half long, the ends being square, he could easily (as with a rammer) drive down one wedge upon the other, very gently at first, so that the opposite pairs of wedges being equally tightened, they would equally resist each other, and the stone would therefore keep its place; and in this manner those wedges might be driven even more tight than there was occasion for; as the wood being dry, it would by swelling become tighter; and it was possible that by too much driving, and the swelling of the wedges, the stones might be broken; and farther, that a moderate fastening might be effectual, a couple of wedges were also, in like manner, pitched at the top of each groove, the dormant wedge, or that with the point upward, being held in the hand, while the drift wedge, or that with its point downward, was driven with a hammer; the whole of what remained above the upper surface of the stone was then cut off with a saw or chisel; and generally a couple of thin wedges were driven very moderately at the butt-end of the stone; whose tendency being to force it out of its dovetail, they would, by moderate driving, only tend to preserve the whole mass steady together; in opposition to the violent agitation that might arise from the sea.

"After a stone was thus fixed, we never, in fact, had an instance of its having been stirred by any action of the sea whatever; but, considering the unmeasured violence thereof, the farther security by trenails will not seem altogether unnecessary, when we reflect, that after a stone was thus fixed in its place by wedges, a great sea coming upon it, (often in less than half an hour) was capable of washing out all the mortar from the bed underneath it, notwithstanding every defence we could give it by plaster or otherwise; and that when the bed of mortar was destroyed, the sea acting edgewise upon the joint, would exert the same power to lift it up, that the same sea would exert to overset it, in case its broad base was turned upright to oppose it; and as the wedges only fixed and secured the several pieces of which each course consisted, to each other, and had no tendency to keep the whole course from lifting together, in case the whole should lose its mortar bed; it seemed therefore highly necessary to have some means of preventing the lifting the whole of a course together, till the solidity and continuity of the mortar should totally take away that tendency. Adverting now to what was said, that a couple of holes, to receive oak trenails of one inch and three quarters in diameter, were bored in the work-yard through the external or projecting end of every piece of stone: we must now suppose these stones set in their places, and fixed by wedges; then one of the tinners, with a jumper, began to continue the hole into the stone of the course below, and bored it to about eight or nine inches deep: but this hole was bored of a less size, by one-eighth of an inch in diameter, than the hole through the stone above; in consequence, the trenails, having been previously dressed with a plane till they would drive somewhat freely through the upper hole, would drive stiffly into the under one, and generally would become so fast as to drive no

farther before their leading end got down to the bottom; and if so, they were sufficiently fast: but as they sometimes happened to drive more freely than at others, the following method was used to render them fast, for a certainty, when they got to the bottom. The leading end of every trenail was split with a saw, for about a couple of inches, and into this split was introduced a wedge, about one-eighth of an inch less in breadth than the diameter of the trenail; it was a full quarter of an inch in thickness at the head, and sharpened to an edge; when therefore the head of the wedge touched the bottom of the hole, the trenail being forcibly driven thereupon, would enter upon it, till the whole substance was jambed so fast, that the trenail would drive no farther; and as the wood would afterwards swell in the hole, and fill the little irregularities of boring by the jumper, it became so fast, that, as it seems, they could sooner be pulled in two than the trenails be drawn out again. The trenail (originally made somewhat too long) being then cut off even with the top of the stone, its upper end was wedged cross and cross. There being generally two trenails to each piece of stone, no assignable power, less than what would by main stress pull these trenails in two, could lift one of these stones from their beds when so fixed, exclusive of their natural weight, as all agitation was prevented by the lateral wedges. The stone being thus fixed, a proper quantity of the beat mortar was liquefied, and the joints having been carefully pointed up to the upper surface, the grout so prepared was run in with iron ladles, and was brought to such a consistency as to occupy every void space; and though a considerable part of this was water, yet that being absorbed by the dry stones, and the more consistent parts settled to the bottom, the vacuity being at the top, this was repeatedly refilled till all remained solid: the top was then pointed, and, when necessary, defended by a coat of plaster.

"The several courses, represented in *Plate* III. are shown as they would appear, when completed with the whole of their wedges and trenails: and besides these, there being also generally two lewis holes upon the upper surface of each stone, those served as temporary fixtures for the work of the succeeding course.

"It was the same evening's tide, of the 11th of August, that the basement was completed and the centre stone of Course VII. was landed. Of the preceding courses, each was begun by the stones that engrafted in the dovetail recesses cut in the rock; these stones, therefore, being immovable by any assignable force acting horizontally, rendered those so likewise that depended upon them; but having now brought the whole upon a level, we could not have this advantage any longer; it therefore became necessary to attain a similar advantage by artificial means. For this purpose, the upper surface of Course VI., (*Plate* III. *Figure* 6.) had a hole of one foot square cut through the stone that occupied the centre; and also eight depressions, of one foot square, sunk into that course six inches deep, which were disposed at regular distances round the centre: these cavities were for the reception of eight cubes of marble, in masonry called joggles. As a preparation for setting the centre stone of Course VII., a parallelopiped (which, for shortness sake, I will call the plug) of strong hard marble from the rocks near Plymouth, of one foot square and twenty-two inches in length, was set with mortar in the central cavity, and therein firmly fixed with thin wedges. Course VI. being thirteen inches in height, this marble plug, which reached through, would rise nine inches above it; upon this, the centre stone (see *Plate* IV. *Course* VII.) having a hole through its centre of a foot square was introduced upon the prominence of the plug, and, being bedded in mortar, was in like manner wedged (with wedges on each side of the plug) and every remaining cavity filled with grout. By this means no force of the sea, acting horizontally upon the centre stone, less than what was capable of cutting the marble plug in two, was able to move it from its place: and to prevent the stone more effectually from being lifted, in case its bed of mortar happened to be destroyed, it was fixed down in the manner above described, by four trenails; which being placed near to the corners of the large square of that stone, they not only effectually prevented the stone from lifting, but aided the centre plug in preventing the stone from moving angularly, or twisting, which it might otherwise have done, notwithstanding its weight, which was two tons nearly.

"After setting the first centre stone of Course VII. we immediately proceeded to set the four stones that surround it, and which were united thereto, by four dovetails, projecting from the four sides of the centre stone. These stones being fixed in their dovetails by a pair of wedges on each side at bottom and top, as has already been mentioned, and held down by a couple of trenails to each surrounding stone, and still farther steadied by joint wedges at the head of the dovetails, and also in the mitre, or diagonal joints between each surrounding piece; the whole formed a circular kind of stone of ten feet diameter, and above seven tons weight: and which being held down by a centre plug and twelve trenails, became in effect one single stone; whose circumference was sufficient to admit of eight dovetail recesses to be formed therein, so as to be capable of retaining in their places a circle of eight pieces of stone, of about twelve hundred weight each, in the same manner, and upon the same principle, that the radical pieces of stone were engrafted into the dovetail recesses of the rock; and which being in like manner wedged and trenailed, we proceeded with circular tiers of stone, in the manner shown in *Plate* IV. *Figure* 1. It is, however, to be remarked, that the mode of applying the wedges and trenails being sufficiently explained in the several figures of *Plate* III. and also in *Plate* IV. *Figure* 1, to avoid a repetition of small work, the several succeeding figures simply show the general shapes and disposition of the different pieces composing a course, and other incidental larger matters wholly omitting the particular application of the wedges and trenails; yet it is to be observed, that they were everywhere equally applied, till we got to the top of the solid.

"My much esteemed master and friend, Mr. Weston, who came from London to be witness of our proceedings, arrived at Plymouth during this interval. I went off with him early on Wednesday morning, the 17th, attended by Mr. Jessop and his company, and landed upon the rock at ten: Richardson and company were then about to begin to set the fifth tier, or circle of stone, which was to contain the eight cubes before described. These cubes were so disposed upon the surface of Course VI. that the cavities cut on the under side of Course VII. to take the upper half of each cube, should constantly fall in the broad part of the stones of the fifth circle; which will appear plain by considering the dotted lines relative to Course VII. upon the surface of Course VI. (see *Plate* III. *Figure* 6.) There could consequently be no application of wedges in the upper course, to the fastening of the circle of stones, (No. 5,) upon their respective cubes: when therefore the stone respectively came upon them, we put as much mortar upon the top of the cube as would in part make good the joint between it and its cavity, but not enough quite to fill it; because, if too full, there was no ready way for the superfluous mortar to escape; but a hole, of the size of those for the trenails, being previously bored through each of these pieces, answerable to the middle of

each cube; when the stone was set, wedged and trenailed, then it was very practicable, by dressing a trenail so as to become a ram-rod, to drive as much mortar down the hole as would completely fill every vacancy between the stone and its cube: insomuch that we soon perceived, that if this was attempted before the stone was completely trenailed down, it would very easily raise the stone from its bed, as might indeed be expected from the principle of hydrostatics: but, being done after such completion, it brought the whole to the most solid bearing that could be wished; and, when the cement was hardened, answered the end quite as effectually as if they had been wedged.

"It may here be very properly said, that since those cubes could be of little use in keeping the work firmly together, before the mortar was hardened; and after that had taken place, they could be of no use; because the number of one hundred and eight trenails, of which one of these courses consisted when complete, being supposed sufficient to keep it from lifting and moving out of its place; as the mortar hardened, and every additional course was an addition of its own weight upon the former, if those cubes could have been dispensed with in the first instance, they might have been so ever after. This reasoning I can very well admit to be true; yet, when we have to do with, and to endeavour to control, those powers of nature that are subject to no calculation, I trust it will be deemed prudent not to omit, in such a case, anything that can without difficulty be applied, and that would be likely to add to the security. It may farther be remarked, that as this building was intended to be a mass of stone, held together by the natural and artificial union of its parts, it would have been out of character, that, when completed, it should be beholden to certain parts of wood for its consolidation.

"I have mentioned, that I originally conceived more than one way of preventing the courses from shifting place upon one another. My first conceptions were to form a rise (or a depression) of three inches, bounded by a circle somewhat about the diameter of that in which the joggles are placed; which step, or depression, would have formed a socket, whereby the courses would have been mutually engrafted, not much different from what nature has pointed out in the basaltine columns of the Giant's Causeway; but, considering how much unnecessary trouble and intricacy would be hereby introduced, by one part of the bed of the same stone being liable to be three inches higher than the other, I judged that the end would be very sufficiently answered by the much more plain, easy, and simple method of joggles; especially as, for this purpose, the firmest and toughest kind of stone might be chosen, and the number multiplied at pleasure. One plug in the middle, of a foot square, and eight joggles of a foot cube each, of the hardest marble, disposed in the manner described, seemed to me, along with the additional strength and security arising from the trenails, as also from the infinite number of little indentures upon the surface of the courses, as well as the lewis holes, each being filled with an exuberance of mortar, which, when hard, would in effect become a steady pin; from the cohesion of the mortar as a solid, promising to be no less than that of the stone, together with the incumbent weight of every part of the building above; every joint, thus separately considered, seemed, in point of firmness, so satisfactory to my mind, that if the whole of this proved too little, it was out of my power to conceive what would be enough.

"In the morning and evening's tide of the 17th, we set the whole of the fifth tier, and consequently the whole of the eight cubes were then inlaid. The morning of the 18th we again landed, and in this morning and evening's tide, though rough, we had got set five pieces of Circle VI. and had landed the remaining three; as also one of the largest pieces of moor-stone for the east side (see *Plate* IV. *Figure* 1.) This evening's tide we worked with links, and it began to blow so fresh that we had much ado to keep them in, being obliged to make a fire of them upon the surface of the work. We were under the necessity, at last, to quit the rock with some precipitation, and were very glad to get into our yawls; things being left in the following posture: Two of the pieces, Tier 6, were simply dropped into their places, on the north-west side, while the third piece, being about a ton, and the piece of moor-stone near upon two tons, were chained together, and to the work of Course VII. that was already set; these two loose pieces being upon the top of that course, near the east side; the triangles we lashed down upon the floor of the work, as we had practised several times before. The sea became so rough in the night, that the Weston, at the transport buoy, was obliged to slip and make for a harbour. The bad weather continued to increase till the 28th, when there was a violent storm at south-west.

"The 29th, I perceived with my telescope, from the Hoa, the buss to ride safe, but could not see the shears, or indeed anything else upon the rock distinctly, except the breakers. The day following being more clear, and the sea somewhat subsided, I immediately went on board the Eddystone boat to reconnoitre. The wind being north-west, I passed the rock several times under sail, but there was no possibility of landing. I observed, that not only all the work which had been completely set was entire, but that the two stones mentioned to have been simply lowered into their places, also remained therein, and that the five hundred weight still rested upon the stone whereon it was left. The west face of the building had got so complete a coat of sea-weed, that it was only distinguishable from the rock by its form; but the shears and triangles were entirely gone; the two pieces of stone, that had been chained together and to the work, were also gone; the windlass frame broken and much damaged, and the roll gone; the fender piles and the transport buoy, however, remained in their places.

"It was the 3rd of September before the company could make a landing to do anything upon the rock; so that, since the 18th ult., there had been an interval of fifteen days, in which we had been totally interrupted by bad weather, in the very prime part of the season. However, everything having been expedited on shore, to get refitted for work, this day I went out therewith, and began to set up our new shears, windlass, &c., and with the shears got up the piece of Portland, of Circle 6, which was set, as also the others that had been left loose in their dovetails; but the tide of flood coming on, had deepened the water too much before we could try to get up the other.

"September the 5th, the seventh circle was finished and the eighth begun; and this day the wind being variable, from north-east to north-west, and very moderate, was very remarkable, as being the first time of the people having worked 'till they were obliged to quit the rock for refreshment: and now everything being reinstated, it was some time before we met with anything but the ordinary interruptions.

"The fineness of the season continued to favour the expediting of our works, insomuch that Course VIII., which was begun upon the 8th, was executed in five days, being entirely completed on the 13th, at the same hour. Everything went regularly on till the 20th; so that, in return for our continued interruption from the stormy weather for fifteen days, our works had an uninterrupted progression for eighteen days, when Course IX. was advanced to the fifth circle."

A series of land-swells from the south-west prevented

further proceedings till the 30th September, when Course IX. was completed, "and the masons proceeded to rectify the face of the work, where it was in any degree wanting thereof, that there might be no need hereafter to disturb any part of the coat of weed, which was likely to fix upon it during the winter." This ended the operations for the year 1757.

On the 12th of May, 1758, Mr. Smeaton examined the work, and found it perfectly entire, except a small spawl, which had been washed from the rock itself; the whole did not seem to have suffered a diminution of so much as a grain of sand since the time he left it on the 1st of October of the preceding year: on the contrary, the cement, and even the grouted part, appeared to be as perfectly hard as the Portland stone itself; the whole having become one solid mass, entirely covered with the same coat of sea-weed as the rock, the top of the work excepted. This was washed so clean and white, that the lines upon it appeared more distinct than when they were in the work-yard; the cube-holes and lewis-holes, however, from their being constantly filled with water, were grown over with green weed, like the outside. The fender piles were indeed all gone, but this was a trifling disaster, as they could soon be renewed.

The tenth course was set on the 5th of July, the eleventh on the 18th, the twelfth on the 24th, the thirteenth on the 5th of August, and on the 8th of that month the fourteenth, which completed *the fundamental solid.*

From the top of this course begins that part of the building, also called the *solid*, which includes the passage from the entry door to the well-hole of the stairs as described *Plate* IV. *Figures* 2, 3, 4, from which a more adequate idea can be obtained than any words could convey.

Mr. Smeaton then proceeds to describe his method of regulating the superstructure: As "for the sake of the well-hole, we must necessarily lose our centre-stone, the four stones, which in the former courses were united to it by dovetails, were, as now prepared, to be united to each other by hook-scarf-joints, so as to compose, in effect, one stone: and as, in consequence, we had also lost our centre cubes, it became expedient, that the work might have a uniform texture and strength, that those four stones, making a complete circle for the staircase, should be provided with cubes, to prevent their being shifted by any shock applied horizontally, (see *Figure* 4,) as well as with the trenails to hinder them from lifting. By this means the principle of consolidation would be effectually preserved: but as the top of the fourteenth, or entry-door course, was twelve feet above the top of the rock, that is, twenty feet four inches above the base of the first course, the stroke of the sea must here become less violent, and therefore a less degree of resistance would be equally sufficient. And as the large cubes would too much cut the work, which was here of considerably less area; and as several cubes would be requisite for the well-hole stones, I had determined, above the entry-door course, to increase the number of cubes from eight to sixteen, and to diminish their size from twelve to six inches; but still to be of solid gray marble, and two of them to be introduced into each of the four well-hole stones.

"Upon the 9th of August, I marked out the entry and staircase; and having unloaded the Eddystone boat, which was loaded with the first pieces of Course XV., we immediately proceeded with it; and from this time were blessed with such an uninterrupted continuance of fine weather, that upon the 20th of August, Course XVIII. was completed, which reunites the building into a complete circle, by covering the passage to the staircase: the external face of the stone of that course which makes the cover or head of the entry-door having the figures 1758, denoting the year in which this part of the work was accomplished, cut in deep characters upon it.

"On the 24th of August, the fine weather, and in consequence the works, were interrupted, Course XX. being then in hand; and it was not till the 24th of September, that, with every possible exertion, Course XXIV. was finished, which completed the solid, and composed the floor of the store-room.

"The 25th and 26th of September, Course XXV., being the first course of the superstructure, was successfully completed in its place; but, as the mode of construction now became entirely different from the former, it is necessary to give an account thereof, as also of the reasons for the change. The building was carried up solid, as high as there was any reason to suppose it exposed to the heavy stroke of the sea; that is, to thirty-five feet four inches above its base, and twenty-seven feet above the top of the rock, or common spring-tide high-water mark. At this height, as it was reduced to sixteen feet eight inches in diameter, it became necessary to make the best use of this space, and make all the room and convenience therein that was possible, consistent with the still necessary strength. The rooms being made of twelve feet four inches diameter, this would leave twenty-six inches for the thickness of the walls. These being made with single blocks in the thickness so that sixteen pieces might compose the circle, would, from its figure, compose a stout wall; yet moor-stone, as has been observed, being a tender kind of stone, in respect to the union of its component parts, any method of dovetailing the blocks together, at this thickness, appeared to me impracticable to any good purpose. What seemed to be the most effectual method of bonding the work together, was that of cramping with iron, which would confine each single piece to its neighbouring piece in the same circle: and if to this be added, that every piece should, at each end of it, lay hold of an inlaid piece, or joggle in the same nature as the cubes, then not only all the pieces in the same course would be united to each other by the cramps, but steadied from moving upon the under course by the joggles, and of consequence would be fastened at thirty-two points: for in each course there being sixteen joggle-stones, as each end of each principal piece, at its base, took hold of half a joggle, there would be thirty-two points of confinement in the circle above; that is, the joggles being made to occupy the middle of the upper bed of each block, in that situation they would cross the joints of the course above. These joggles, as well as the rest, were of sawn marble, and made eight inches long, four inches broad, and three inches thick: each end of each block, therefore, would occupy four inches in length, four in breadth, and one inch and a half in the height of each joggle; and this I judged quite sufficient to keep every course in its place, at the height that this kind of work was begun, and so as to constitute a piece of solid masonry. There was, however, another matter, that it seemed quite material also to attend to; and that was, to render the habitable rooms contained within those shells of walls, perfectly dry and comfortable in all weathers; and this seemed to merit very particular attention; for the seas that are said to rise up against, and in a manner to bury the house, in time of storm, would make effectual trial of every joint.

"The level joints being pressed together by the incumbent weight of the building, would keep firm and sound that cohesion of parts produced by the mortar; so that once being made water-tight, there was no doubt that they would so remain: but with respect to the upright joints, the least degree of shrinking, either of the stone or of the mortar

between, tended to open the joint, so that it might always remain leaky, in a greater or a less degree; for we know of no degree of separation of parts, however minute, short of absolute contact, which will stop or prevent the percolation of water. For this purpose I conceived that if flat stones were introduced into each upright joint, so as to be lodged partly in one stone, and partly in its neighbour, (much upon the same idea that Dutch laths were formerly introduced into the joints of chamber floors, to hinder the passage of wet,) the water might be prevented from making its way through the upright joints of the walls.

"The manner in which it was executed was as follows: (see *Plate* IV. *Figure* 6.) At each end of each stone, answerable to the middle between the inside of the wall and the outside, was sunk a groove, two inches and a half wide and three deep, running from the top to the bottom: when, therefore, two contiguous pieces of stone were put together in their places, the two grooves being applied to each other, they would form a rhomb of six inches in length and two inches and a half in breadth, which in this state would be an unoccupied cavity from the top to the bottom of each course; the rest of the joint, where the surfaces of the two stones applied to each other, was made good with mortar in the ordinary way, and brought together by the gentle blows of a beetle. For the groove mentioned, a solid rhomb was prepared, of about two inches thick by five inches broad, and in length a little less than the depth of the cavity, which generally was eighteen or twenty inches; and for the sake of the firmness of those slender pieces of stone, I made choice of the flat paving-stones from Purbeck, which is a laminated marble of great strength and solidity. The joint-stones (which was the name we gave those rhombs) thus prepared, would readily go down the cavities; but, to fix them solid, a quantity of well-tempered mortar was prepared, made more soft than ordinary, by the addition of a little water; a competent quantity being put down to the bottom of the hole, the joint-stone was put down upon it, and, by the simple pressure of the hand, was forced down to the bottom, causing the semifluid mortar to rise up to the top, and completely fill the cavity; and, when forced down in the way described, having in this state a small quantity of superfluous moisture about it, a few very gentle blows, or raps, were given upon the top of it by the handle of a mason's trowel, which producing a small degree of agitation, while the dry stones were absorbing the moisture, contributed (like the beating of mortar) to bring all the parts into their most friendly state of contact, and, in consequence, to their firmest state of union; and this happened in the course of a few minutes, so that no farther agitation could be of any service.

"As the cramps, that were to bind the contiguous pieces together, must cross the joints upon their upper surface, they were of course to be applied after the joint-stones were settled in their places. Precaution was therefore necessary not to apply too much exertion in forcing down the joint-stones: for, however gentle the operation may appear, according as it has been described, yet it was found advisable not to put in the joint stones till an additional piece had been got down upon its joggles, and plain-jointed at each side of the two pieces, whose joint-stone was to be put in; for, by this means, they were the united efforts of all the joggles, and adhesion of the beds of two stones on each side of that where the effort was applied. Without any attention to this, the lateral force arising from merely pressing down a joint-stone was capable of breaking the adhesion of the joint where it was applied.

"The cramping was applied the last thing. The top or flat bars of the cramps were about thirteen inches long, two inches broad, and five-eighths of an inch thick, and were turned down at each end about three inches in length; forming a cylinder of one and one-eighth of an inch in diameter. Jumper-holes were previously bored when upon the platform, and the cramps fitted to their places; the surface of the stone under each cramp being sunk three-fourths of an inch, so that the two stones together would completely receive, or rather bury, the cramps: the joint-stones, as said above, being made so much shorter than the height of the course, as not to interrupt the bedding of the cramp. The places for the cramps being properly fitted and cleared, (as we now were not liable to be driven off the work in a moment, as had formerly been the case,) we took the opportunity, whenever time allowed it, of fixing the cramps of a whole course together. There was no danger of the cramps not fitting; as, besides that all the cramps were forged to fit a guage-bar having a couple of holes at the assigned distance, they were also fitted and marked to their particular places at Mill Bay, while upon the platform. Every cramp being now ultimately tried to its place, it was then put into a kettle of lead, made red hot; and the cramp continued there till it was also reddish. About a spoonful of oil was poured into the two cramp-holes, and the cramp being put into its place, the ebullition of the oil caused by the heat of the iron quickly gave a complete oily surface, not only to the whole cramp, but to the whole unoccupied cavity in the stone; then the hot lead being poured upon it, the unctuous matter caused the metal to run into and occupy the most minute cavity unfilled, and completely to cover each cramp; and they became by this means defended from the salts of the sea, even had they remained uncovered, upon Mr. Rudyerd's principle. Mr. Rudyerd had used coarse pewter. The lead we used was slag lead, which is harder and stiffer than fine lead: and, as we used no cramps, as an essential part of the building, till above the store-room floor, I judged pewter, merely for the sake of stiffness, there to be unnecessary. By cramping, in general, a whole course together, the contraction of the iron in cooling would greatly add to the tightness wherewith every stone was bound to its fellow. Thus according to this mode of fixing, (besides the union of the parts by the mortar itself,) to resist all violence and derangement whilst it was doing, and before the induration of the mortar, every course was retained in its place by sixteen joggles, and each single stone by two half-joggles at its lower bed; they were farther steadied to each other by the joint-stones, and lastly by the cramps, which completely prevented a separation; and this method proved so effectual, that we were not only free from all derangement of the stones when in their places, but I did not find a leaky joint, except one, in the whole building. By a due consideration of *Plate* IV., with the particular references to it, the whole of this process will become perfectly intelligible.

"On Saturday, the 30th of September, Course XXVIII. was completely set; and, being the first course upon which was rested the vaulted floor, which made the ceiling of the store-room and floor of the upper store-room; and, as here again occurred a difference in the mode of fixture, in this, as in all like cases, I attended the performance of the work: and that was the leading-in of the first circular chain, that was lodged in a groove cut round the middle of the upper surface of this course, which this day was satisfactorily performed; and the next day, Sunday, October the 1st, Course XXIX. was set, and its circular chain leaded-in also; which operation, with the reason thereof, it will be proper here to describe: The ordinary way of fixing the several courses by joggles and joint-stones, and also the bonding them

together by cramps, has already been described; but those courses, upon which the floors rested and depended, seemed to demand every possible security. It will be seen, in the ıeral section, *Plate* II. that each floor designedly rested upon two courses: it will also appear, by inspection, that the circumference of the floors was not made to rest upon the sloping abutments of an arch, in lines tending toward the centre of the sphere, of which the under side of the floor was a portion, but it rested upon a triple ledge going circularly round the two supporting courses. In consequence of this, had each floor been composed of a single stone, this lying upon the horizontal bearings furnished by these ledges, would, while it remained entire, have no lateral pressure or tendency to thrust out the sides of the encompassing walls: and that in effect, the several pieces, of which the floors were really composed, might have the same property as whole stones, the centre-stone was made large enough to admit of an opening, from floor to floor, or man-hole, to be made through it; and being furnished with dovetails on its four sides like those of the entire solid, it became the means by which all the stones in each floor were connected together; and consequently, the whole would lie upon the ledges like a single stone, without any tendency to spread the walls. But if, by the accident of a heavy body falling, or otherwise, any of those stones should be broken, though this might not destroy its use as a floor, or its properties as an arch; yet the parts would then exert their lateral pressure against the walls: and therefore, as a security against this, it became necessary that the circle of the enclosing walls should be bound together, and the building, as it were, hooped.

"This would be in a great measure brought about by the cramps tying the neighbouring stones together, as already described, for the ordinary courses; but yet this was no absolute security, because the outside stones might break and separate, between cramp and cramp: and I suppose, it was for reasons of this kind, that Sir Christopher Wren, in the construction of the cupola of St. Paul's, did not choose to depend upon cramping the stones together, of the course that served as a common base to the inside dome, and the cone for supporting the lantern; but chose to surround the whole with continued chains of iron. Upon this principle, an endless chain was provided for each of the two floor courses; see *Plate* IV. *Figure* 7. The bars composing the links being one inch and a quarter square, that the most iron might be included in a given space, the corners only were a little canted off; and the double parts being brought near together, the whole was comprehended in a groove, of somewhat less than four inches wide, and as much in depth; into which the chains being introduced and brought to a stretch, the rest of the cavity was filled with lead, of which each took about eleven hundred weight, in the following method. The chains were oiled all over before they came from the shore; and the circumference of the groove was divided into four parts by stops, or dams of clay, to prevent the lead from flowing farther than one quarter at a time. A couple of iron kettles were provided, capable of melting commodiously, when full, six hundred weight of lead each; and that quantity was brought in each to a full red; that is, somewhat hotter than we used for the cramps, as the iron of the chain, as well as the stone, were cold. The whole quantity of lead being brought to a heat that we judged proper, and the quarter-groove being supplied with oil sufficient to besmear the whole surface, two persons, with each a ladle, as briskly as they could, poured the melted metal into the same quarter of the groove; and, as soon as it was full, and the lead began to set, one of the clay dams was removed, and the melted hot metal was poured upon the end of the former mass, till it was perceived to re-melt and unite with the fresh metal. This done, the dam at the other end of the first-run mass was taken down, to prevent its cooling more than was necessary, and the third quarter was treated like the former; the end of the mass rendered solid by cooling, being re-melted by the fresh hot metal: lastly, both the remaining dams being taken down, and the metal at each end having a considerable heat, it was found practicable to dissolve both the ends of the former masses: first applying both ladles to that which had had the greater time to cool, and afterwards to the less: by this means the whole was brought to a solid consistence, and the chain entirely buried in the lead. It is, however, to be remarked, that to preserve proper impressions in the lead, for the joggles of the course above, those impressions were made by confining down bricks in proper places, which, when removed, the proper marble joggles were set with mortar in their places.

"Monday, October 2, we proceeded to set up the centre, composed of sixteen ribs, (see *Plate* VIII. *Figure* 3,) for putting the floor together upon; but the weather continued broken till Saturday, the 7th, on which day the Eddystone boat came out, having on board the roof, or platform, for covering the building, and protecting it from the entrance of the downfall spray; together with the doors, iron work, and timber for fitting up the same for habitation. This afternoon we landed, and went on with the setting of the outward circle of floor-stones, made the holes in the wall for fixing the hinges of the entry and store-room doors. In particular, I caused the middle stone to be laid upon the centre, by way of weight, to keep it steady. Three of the four stones that were to connect with the centre-stone were laid upon the top of the wall, on the north-east side: and the fourth I caused to be hoisted and suspended upon the triangle, in the posture that is shown *Plate* VI. at stage second. So that the triangle, which was all of it completely within the area of the top of the building, would be kept down by the weight of this stone, which was between seven and eight hundred weight. The other three that lay upon the wall, I caused to be carefully drawn within the circumference thereof, so that there might not be the least projecting part for the water to strike against in flying upwards; which I judged quite necessary, though the walls were then upwards of forty-three feet above the foundation-stone, and near thirty-five feet above the top of the rock."

The weather now set in so bad, that no farther operations of consequence took place that season. On the 10th of October, Mr. Smeaton was mortified with a copy of a resolution of the Trinity-Board, declining his proposal of exhibiting a light that winter upon the foundation of the building.

"During my stay in London, in the early part of the year 1759, I received regular accounts of the proceedings at Mill Bay, which were carried on with all the dispatch I could wish; but the weather having continued unfavourable to visiting the works at the Eddystone during the winter, I got no report thereon till I received Mr. Jessop's letter, dated the 27th of March, wherein he informed me that on the 21st of that month, being the first opportunity he could catch after the violent storm which had happened on the 9th preceding, they found not only the solid, but the hollow work perfectly sound and firm; all the mortar having become quite hard; and, in short, every part of the work in the situation in which it was left by the workmen in October: the only derangement was, that the sea had carried away the south fender pile from the rock; and also, from the top of the wall, one of the three stones that I had taken care to draw within the verge of the circumference of the wall, as mentioned. They had found the fourteen pieces of stone set in the circum-

ference of the floor, stuck quite firm to the wall, though two of the pieces requisite to complete the circle were left unset; and that, finding the centre itself quite tight and firm underneath them, they had lowered down the stone suspended on the triangle upon it, and removed from the wall the other two remaining stones to lie upon the centre; and lastly, that they took down the triangle, and stowed it away in the well-hole for the stairs: but, on farther search, nothing of the buoy that was left upon the mooring chains was to be seen.

"Thursday, the 5th of July, I landed on the rock with the men; they proceeded to set up the shears and windlass, while I inspected the work; and found everything perfectly sound and firm, without the least perceivable alteration since we left it; except that the cement used the first year, now in appearance approached the hardness of the moor-stone; and that used the last year, of the full hardness of Portland. We now proceeded to set the floor. The two remaining pieces of the outmost circle, which were left uncompleted last year, were soon set; and we proceeded to haul up the stones for the next circle (No 4.) from the store-room.

The work now proceeded so rapidly, that the second and third stories were completed in thirteen days. On the 8th of August, Course XLV. or the Cove Course, was completed with its two chains; and the next day, the elliptical centre for the balcony floor was set; and by the 16th, the interior area of the balcony floor was completed, the centre was struck, and the outer circle of stones which finished the cap of the main column, being parts of the corona, or cornice, was begun upon. *See Plate* II. and *Plate* IV. *Figure* 9.

"Friday, August the 17th, the last pieces of the corona were set, and therewith the main column was completed. I now examined the perpendicularity of the whole building, by letting fall a plumb-line from the centre of the man-hole in the balcony floor to the centre of the bottom of the well-hole, being forty-nine feet and a half; and found it to fall a small matter to the eastward of the centre of the well-hole; as near as I could determine it, not more than one-eighth of an inch. I then measured the perpendicular heights of the several parts of the building, and found them as follows:

	Ft.	In.
"The six foundation courses to the top of the rock	8	$4\frac{3}{4}$
"The eight courses to the entry door	12	$0\frac{1}{2}$
"The ten courses of the well-hole to the store-room floor	15	$2\frac{1}{4}$
"The height of the four rooms to the balcony floor	34	$4\frac{1}{2}$
"Height of the main column, containing forty-six courses	70	0

"We proceeded this day to set up and lead-in the balcony rails, and completed them; and having brought out a temporary cover for the man-hole of the balcony floor, I this day applied it to use, as follows: a short tub, of about a foot high, was made without a bottom, and the smaller end of it being sized as near as possible to the man-holes of the floors, it was driven into that of the balcony; and, by the time it was driven about four inches, the compliancy of the wood to the stone rendered it quite tight; then the rest of its height, forming a border, and standing about eight inches above the floor, would prevent water from dripping into the rooms through the upper man-hole, or hatchway; and having also provided another tub, about nine inches deep, having a strong bottom in it, and so much more in diameter than the other, that it would, when inverted, cover it; this being applied as a cover, would in the greatest stress of weather defend the building from the entry of water at the top."

On the 18th of the same month, the first course of the lantern was begun; on the 24th, the last stone, being that which makes the door-head of the lantern, was set; and on Sunday evening, the 26th, the whole of the masonry was completed.

Stress of weather prevented the landing of the frame-work till Saturday, the 15th of September; on which day, "between three and four in the morning, the Weston was got into the gut, and delivered of her cargo, consisting of the pillars, sashes, and frame-work of the lantern. I gave my principal attention to the establishing the frame of the lantern upon a bed of lead, and the screwing of it carefully together; seeing that every joint was filled, and screw covered with white-lead and oil, ground up thick for paint; and every crevice so full that the bringing the screws home made the white-lead matter to ooze from every juncture; thereby to exclude all wet and moisture, and so as to prevent the iron-work from rusting.

"Sunday, September the 16th, was remarkably fine; so that by the evening the whole frame of the lantern was screwed together, and its groundsill was rested upon a bed of lead; which was done in the following manner: The whole frame being screwed together, was raised from its bearing upon the stone about three eighths of an inch, by a competent number of iron wedges; and adjusted by them to an exact perpendicular. Both the stone and the iron were taken care to be oiled before they were applied to each other; and one of the eight sides, having its wedges withdrawn, was run with hot lead; and making a place for it to overflow, as much could be used as would competently heat both the iron and stone, to bring them to a close bearing with the lead; then on the lead's cooling, as the frame became supported on one side by the lead, the wedges of a second side were withdrawn, and treated in the same manner, and so successively till the whole rested upon a solid basement of lead. It was not supposed that the succeeding mass could be sufficiently heated to re-melt the ends of the parts already leaded, as in the case of the chains: but being heated so as to bring them to a close contact, this I judged sufficient, as the lead so applied had no other intent but to bear weight, and give the frame of the lantern one solid uniform bearing.

"Monday, the 17th. This morning was also exceedingly fine; and the Weston being in sight, which was appointed to bring out the cupola, we began to set up our shears and tackle for hoisting it. This perhaps may be accounted one of the most difficult and hazardous operations of the whole undertaking; not so much on account of its weight, being only about eleven hundred, as on account of the great height to which it was to be hoisted, clear of the building; and so as, if possible, to avoid such blows as might bruise it. It was also required to be hoisted to a considerable height above the balcony floor; which, though the largest base we had for the shears to stand upon, was yet but fourteen feet within the rails; and therefore narrow, in proportion to their height. The manner in which this was managed, will, in a great measure, appear by the representation thereof, in *Plate* VI. (see the uppermost stage); but is more minutely explained in the technical detail of that Plate. As the legs of the shears that had been used upon the rock would have been in the way of the cupola they were now removed, as being done with there, and were used as a part of this machinery. About noon the whole of our tackle was in readiness; and in the afternoon the Weston was brought into the gut; and in less than half an hour her troublesome cargo was placed upon the top of the lantern, without the least damage.

"Tuesday, September the 18th, in the morning, the wind was at south-east, with intervals of thick fog; however,

between those I had the satisfaction, with my telescope, to perceive the Eddystone boat, on board of which I expected the ball to be. The wind and tide were both unfavourable to the vessel's getting soon near us; therefore being desirous to get the ball screwed on, before the shears and tackle were taken down, one of the yawls was dispatched to bring it away. This being done, and the ball fixed, the shears and tackle were taken down. By this time the joiners had set up and completed the three cabin bedsteads, (for their plan and position between the windows, *see Plate* IV. *Figure* 8.)

"On Friday, the 21st, all the copper sash-frames were got completely fixed in, and ready for receiving the glass.

"On Sunday Morning, the 23d, the yawl landed two glaziers and a coppersmith, with their utensils and materials; the former began to glaze the lantern, and the latter to fit and put up the funnels. This day, with my assistant, the mason, I began to fix twenty-four iron cramps; that is three to each rib of the roof, and which were obliged to be fixed after the roof was together; and being fixed inside, and surrounding the ribs, served to key home the plates of the cupola to the ribs. For this purpose small wood wedges were used, as being more supple, elastic, and compliant, than wedges of metal, and therefore more suitable to this particular purpose. This day also the Eddystone boat brought out and landed a plumber, with his utensils and materials. The most considerable work for the plumber was the covering the whole balcony floor with thick plates of lead; and which extended from the top of the plinth, or first course of the basement of the lantern, quite down to the drip of the corona. They were fitted on separately, in sixteen pieces, and soldered together, in place, with strong ribbed joints; and, to prevent the sea from laying hold of them at the drip, and beating them up, they were turned under about one inch and a half; and being near half an inch thick, I judged them sufficiently stubborn to prevent being unripped.

"Thursday the 27th, the lead-work upon the balcony and corona being now entirely finished, and the cupola completely keyed home to the ribs; the straps and bolts were applied at each angle of the lantern, for screwing it down to the floor of the balcony.

"Friday, September the 30th, the joiners finished their work, which consisted of the following articles. Three cabin beds, to hold one man each, with three drawers and two lockers in each, to hold his separate property, which were fixed in the upper room, or chamber. (See plan thereof, *Plate* IV., *Figure* 8.) In the kitchen, besides the fire-place and sink, were two settles with lockers, a dresser with drawers, two cupboards, and one platter case. (*Figure* 7, of the same *Plate*, shows how these were disposed.) In the lantern a seat was fixed, to encompass it all round, the doorway excepted, serving equally to sit upon, or stand to snuff the candles; and to enable a person to look through the lowest tier of glass panes at distant objects, without having occasion to go on the outside of the lantern into the balcony. Besides the above, the joiners had fixed the ten window-frames, with their sashes; all which were bedded in putty, and falling into rebates cut for them in the original formation of the stone, they could be at any time removed, and replaced at pleasure, as they were fastened in only with wooden pins, driven into holes bored in the stone."

On Michaelmas-day, the glazing of the lantern was completed; on the 1st of October, the copper funnel was finished and tried by lighting a fire in the stove.

"The tackle was also fixed for raising and lowering the chandeliers; and those being hung, there was now nothing to hinder our making trial by lighting the candles, while it was daylight, to see that everything, regarding the light, operated in a proper manner. Accordingly, this afternoon, we put up twenty-four candles into their proper places, and continued them burning for three hours; during which time we had a very effectual trial; for it had blown a hard gale of wind at south-east all day, which still continued; and, keeping a fire at the same time in the kitchen, they both operated together without the least interference; not any degree of smoke appearing in the lantern, or any of the rooms: and, by opening the vent-holes at the bottom of the lantern, it could be kept as cool as we pleased; whereas, in the late lighthouse, this used to be complained of, as being so hot, especially in summer, as to give much trouble by the running of the candles.

"Wednesday, October the 3d, we began to fix the conductor for lightning. As the copper funnel reached through the ball, and from thence came down to the kitchen floor, above forty feet, (see *Plate* II.) I considered this as containing so much metal, that, if struck with lightning, it would thus far be sufficient conveyance; then joining the kitchen grate to the leaden sink, by a metal conveyance, the sink pipe of lead would convey it to the outside. From the sink pipe downwards, which being on the north-east side, was consequently the least subject to the stroke of the sea, we continued the electrical communication by means of a strap of lead, about one inch and a half broad and three-eighths thick, fixed on the outside by being nailed to oaken plugs, driven into two jumper-holes in the solid of each course; the prominent angles of the strap being chamfered off, it was bedded and brought to a smooth surface with putty. At the foot of the leaden strap, an eye-bolt of iron was driven into the rock; and to this was fixed an iron chain, long enough to reach at all times into the water; its lower end being left loose to play therein, and give way to the stroke of the waves: by this means an electrical communication was made from the top of the ball to the sea."

Everything being now completed, notice was sent to the Trinity House, and, on Tuesday evening, the 16th of October, 1759, the lights were first exhibited, amidst the fury of a violent storm.

This excellent building exhibited no other light than what was produced by twenty-four candles, which was not always sufficient, till 1809, when Mr. Robinson, surveyor of lighthouses to the corporation of the Trinity House, superseded these candles by the same number of Argand lamps, each accurately fixed in the focus of a large parabolic reflector of richly plated copper, arranged on circular frames; and consequently giving light in every direction. The improved brightness of the light, by this exchange, exceeded the most sanguine expectation of all in the neighbourhood of Plymouth.

TECHNICAL REFERENCES TO THE PLATES.

"*Plate* I.—*A plan and perspective elevation of the Eddystone Rock, as seen from the west; showing also the theodolite.*

"The representation is as I found the rock; *Figure* 1 being the plan, and *Figure* 2 the upright view. The same letters refer to the same parts in both; the cross lines upon the plan answer to the cardinal points, east, west, north, and south, according to the true meridian.

"L is the landing-place, and C the summit of the rock; the general declivity being towards the south-west; the grain of the laminated moor-stone that composes it being nearly parallel thereto. It has, however, considerable irregularities; for upon the line A B the rock makes a sudden drop of four and a half or five feet; and, by overhanging to the westward, when there is a ground-swell at south-west, the sudden check causes the sea to fly in an astonishing manner, even in moderate weather.

"The surface of the rock is shown, as supposed to have been for ages past; except where it is visibly altered by man's hand, chiefly within the circular area of the late building. The flat treads of the steps cut by Rudyerd are marked D; the upright faces of the steps F; and E denotes the spawled parts, parallel to the grain of the rock.

"*a b c d e f g h* show the remains of the cavities of eight of the twelve great irons fixed by Winstanley; of which the stump of one only, viz., that at *e*, remained for my inspection; it was run in with lead, and had continued fast, till in planting a dovetail there it was cut out, and found club-ended. Which of the other holes, that are left unmarked, made up the remaining four, I could not make out; as doubtless several of them appertained to the additional work that he fixed in the fourth year.

"*Figure* 3. A pair of Rudyerd's iron branches, to a scale three times larger than that of the plan; wherein A B is the main branch, or dovetail part; C D the key, driven hard in, but without touching the bottom; their depth in the rock is denoted by supposing the line E F its surface. The holes in the branches served to fasten the timbers, by large bearded spike-bolts. Of those branches I traced thirty-six original pairs, of different sizes; and two more modern: their places are shown in the upright, *Figure* 2, by inspection; and likewise in the plan, *Figure* 1, at 1, 2, 3, 4, 5, and 6, 7, 8, 9, 10, &c. forming a double circle; also two pair of them at K, to fix the mast, on two sides, to the centre. The irons that remained in the rock, are distinguished in the plan by being hatched with slant lines, the empty holes or cavities by being black. Those that remained whole, whether fast or loose, are distinguished in *Figure* 2, by their shapes.

"X. The place of the cave on the east side.

"R. A strong ring-bolt, put into the rock on the recommencement of the building in 1757, for fastening the western guy-chain of the shears.

"*Figure* 2, *r s t v w*. The three-legged stool, steadied with cross-braces. Upon the middle of the upper round plank *r s* was screwed down the theodolite T, to whose index was screwed the long horizontal rule T S, divided into feet, inches, and parts, upon one edge, tending to the centre. Upon any marked point of the rock to be ascertained, suppose *x*, the rod *x y* was set upright by a spirit-level, and was preserved in an upright position by two small slips of deal, applied as shores or struts, in two different directions. The divided edge of the rule being brought against the upright rod, was shoved up by a short staff, held in the hand tight against the rod, till a spirit-level laid upon the top of the rule showed it to be level. In this position the index would show the degree and minute of the circle; the upright rod would mark the distance from the centre upon the rule; and the rule would mark upon the rod, how much the intersection was above its bottom at *x*.

"*Plate* II. No 1.—*South elevation of the stone lighthouse completed upon the Eddystone in* 1759.

"A. The landing-place.

"B. The cave in the east side of the rock.

"C. The steps cut to mount the rock to the entry-door.

"D. An iron rod, serving as a rail to hold by, in passing to the foot of the ladder, occasionally put out from the entry-door at E.

"No. 2.—*Section of the Eddystone lighthouse upon the east and west line, as relative to* No. 1, *supposing it the low-water of a spring-tide.*

"In the section of the rock, A B shows the upright face or drop, marked with the same letters as No. 1, and the line B C shows the general direction of the grain and slope of the rock to the south-westward.

"The dotted line *a b* shows the level of the base of the first stone. The black line *c d* is the base of the stone in the first course that is intersected by the east and west line; and *e f* 1 is the level of the top of the first course, and bed of the second; 2, 3, 4, 5, and 6, mark relatively the tops of the six courses that bring the artificial part of the foundation upon a level with the reduced top of the natural rock; *e* 6 *f*, being the first entire course, marked VII. as being the seventh above the ground-joint.

"*f*. The foot of the temporary ladder; and there is shown the manner in which the ground-joint of the stone-work was sunk into the rock, all round, at least three inches.

"*h*. The first marble plug, or central joggle, that went through the sixth course, and reached half-way through the seventh; and so in succession to the top of Course XIV.

"*i k*. The place of the marble cubic joggles inlaid between each two courses, which were in an octagon disposition round the centre.

"*l*. Smaller cubes between the fifth and sixth course.

"Course XIV. terminates the entire solid; as upon it is pitched the entry and well-hole for the stairs. The temporary ladder, *f g*, to the entry-door D, is only put out when wanted; and then is lashed by eye-bolts to the stone; at other times, having a joint in the middle, it folds, and is laid along in the entry.

"Above the top of the entire solid, the centre stone being omitted to give space for the well, the cubic joggles were of double the number, and half the size. Course XXIV. terminated that part of the building called *the solid:* and here the habitable of the building began, whereof E is the lower store-room.

"F. The store-room door.

"G. The upper store-room.

"H. The kitchen.

"I. The fire-place, from which the smoke ascends through the floors and lantern, through a copper funnel, and through the ball.

"K. The bed-room.

"L. The stone-basement of the lantern.

"M. The lantern door into the balcony.

"N. The cupola.

"The ascent from room to room is by the perforations through the middle or key-stone of every floor; and the detached figures show the means, by inclined step-ladders, removable at pleasure.

"*Plate* III.—*Plans of the rock after being cut, and prepared to receive the stone-building. Showing the six foundation courses.*

"*Figure* 1. Plan of the rock, as prepared for the stone-work, somewhat extended, to show how it applies to *Plate* 1. The line A B shows also here the place where the surface drops, as specified, *Plate* II. No. 2.

"In this figure, Course I. appears in its place, as fixed with its trenails and wedges. The part darker shaded, and marked D D, was not reduced to a dovetail on account of fissures, but was sunk two inches lower than the rest of Course II. The stones laid therein would therefore be encompassed by a border, and held fast in every direction. The letters E. W. N. S. in all the figures, denote the cardinal points; the same letters, in every figure, denoting the same parts.

"The part of the rock marked C, rises above the rest by an ascent, or step, of fifteen to eighteen inches, according to the line D F G E; which, lying somewhat without the general contour of the building, and affording a firm abutment, the advantage was taken; and the work of the first and second course carried against it, as shown at G.

"1, 2, 3, 4, 5, and 6. The level platforms, or steps, for the different courses, whose upper sides are even with these numbers in *Plate* II. No. 2 being upon the level of Rudyerd's lowest step.

"X. A piece of stone engrafted into the rock, serving as a bridge to cross a chasm, opened by cutting down the top of the rock to that level, into the cave. Of this stone is formed a part of the border that encircles the work.

Figure 2 shows how the buttress, G, was terminated in the second course. It also shows the places of the trenails and wedges; which in all these figures are shown in the same manner. The dotted lines everywhere refer to the course that is to come on; and shows how it will break joint upon the course supposed laid.

"*Figure* 3 shows how the space H I K, in *Figure* 2, is filled up in *Figure* 3, being confined in by the rise of the step L at H I, and the cramps *a b;* the ground proving here irregularly shattered by cutting the steps for the former lighthouse.

"*Figure* 4 shows the structure of Course IV., where, in this, as all the others, the stones lighter-coloured denote the Portland, the darker the moor-stone.

"*Figure* 5. The position of three joggle-holes, Y, between this course and the next above.

"*Figure* 6 shows Course VI. complete, which brings the whole work to a level with the reduced rock: it shows the joggle-holes for the eight cubes; and the central plug-joggle, fixed in place at O, ready for the reception of the centre stone of Course VII.

"*Plate* IV.—*Plans of all the different courses from the top of the rock to the top of the balcony-floor inclusive.*

"*Figure* 1. The proper plan of Course VII. relative to the section, *Plate* II. No. 2. As being the first entire course, the trenails and wedges are shown; but afterwards omitted in the draughts, to prevent crowding the figures. The black lines and dotted lines show the joints of the alternate courses. The centre-stones, and the four stones surrounding, were alternately of the same size to the top of Course XIV.

"*a.* The centre plug, first set.

"*b b.* The square part of the centre stone; from each of whose four sides a dovetail projects, and thereon are fixed the four stones *c c*, by joint-wedges and trenails, as per figure; which five stones united make one stone, sufficiently large to receive eight smaller dovetail stones *d d;* and whose projecting parts form dovetails to receive another circle, or order of stones, fixed like the former. The cubic joggles are shown at *e e*.

"*Figure* 2. The plan of Course XIV. ending the fundamental solid, and on which the entry and well-hole are begun. It also shows the diminution from Course VII. Upon this figure is shown the distribution of the smaller cubic joggles, which take place upon the entire solid. The entry here appears to have a small inclination with the E. and W. line, which was not noticed in the section, *Plate* II. No. 2, to avoid ambiguities.

"*Figure* 3. The plan of Course XV. being the first of the entry-door and well-courses.

"*Figure* 4. The plan of Course XVIII. showing the work of the entry closed in, and the solid re-united. Also the manner of hook-jointing the four stones round the centre to each other; which, in the courses below the entry-door, were united by dovetails to the centre-stone. Joint wedges were applied in the hook, as per figure. Thus the arrangement, in circles from the centre, was again complete. In the entry-courses, as every piece had at least one cubic joggle and two trenails, the work was secure against all ordinary attacks of the sea: the weakness being on the east side; but when capped and bonded together by this 18th Course, the whole was again considered as one entire stone, out of which the cavity had been cut.

"*Figure* 5 shows Course XXIII. ready for putting on the cap-course of the solid.

"*Figure* 6. The cap-course, making the store-room floor, in its finished state; the first course of the habitable part of the building, viz. Course XXV. being upon it; and showing the store-room door, with its joggles, joint-stones, and cramps.

"The detached figure, relative to it, shows a part of the top of the wall of Course XXV. to a triple scale; wherein *h h i i* denote one of the pieces of stone, whereof sixteen complete the circle: *f* shows one of the joggles used in this part of the building; being slices of marble the size of a common brick, let half its thickness into the middle of the stone; so that the next course above, breaking joint upon the middle of this, according to the dotted line *g g*, half the joggle's length will take one of the upper stones, whose joint comes upon it, and the other half joggle the other: by which means every stone is fixed to its place, as it were, by two steady pins, one at each extreme. The black lines, *h i*, showing the joint at each end of this stone: the small lozenge figures, *k* and *l*, show the shape of grooves, cut from the top to the bottom of each end of each stone, and which, when two are joined together, form that figure: *k* denotes the lozenge empty, or unfilled, and *l* the lozenge filled with a joint stone.

"*m n.* The shape of one of the cramps, in upright; and *o p* as seen upon the flat. The holes in the stones at *q r* are bored, to receive the round shanks of the cramp, and the rectangular cavities *q r* are sunk, to bury the flat of the cramp *o p*.

"*Figure* 7. The plan of the kitchen floor, and the upper bed of Course XXIX. that encircles it: showing one of the endless chains; of which, as appears in the section, *Plate* II. No. 2, there are two to each floor. The detached figure shows an enlargement of the chain and groove that contains it.

"In the principal figure, the dotted lines at *s* show the place of the fire-grate.

"*t t.* The sink.

"*v v.* The dresser.

"*w w.* The settle.

"*x.* A place for a claw table, leaving a vacancy to the window between each.

"*Figure* 8. The plan of the bedchamber, taken upon the top of Course XLIII. which gives the horizontal sections of the windows.

"*y y y.* The places of the three cabin beds for the light-keepers.

"*z.* The hole in the floor for the copper funnel from the kitchen.

"*a.* The place of the clock.

"In the detached figure, *b b* shows how the cramps are disposed in the reduced jambs of the windows.

"*c.* The plan of the rebate, to receive the shutters, or ports of the windows, whereof the uprights are seen in *Plate* II.

"*d.* The sill of the clear opening; against the solid of which the window frame *e f* and sashes are lodged; the whole of which go in together, and are held in by wooden pins, two above and two below, as shown at *g g*: the holes being bored in the solid stone. If those pins are cut off, the whole can be drawn out and renewed, without injury to the stone-work. The joint of the wood frame with the stone-work is secured against wet by white-lead and oil.

"*Figure* 9. The plan of the cap of the main column, being in *Plate* II. No. 2, the 46th Course, and composes the balcony floor.

"*h h.* The man-hole in the centre, correspondent to the other floors.

"*i.* The funnel hole accordant with *z* in the last figure.

"The dotted lines *k k* trace out the octagon base of the lantern.

"The place of the under rail of the balcony is shown by the dotted lines *m m m*; and *n n n* denote sections of the studs upon which those rails are supported, correspondent to the uprights of *Plate* II.

"*Plate* V.—*Original ideas, hints, and sketches, from whence the general form of the present building was taken.*

"*Figure* 1. The bole of a spreading oak; its side-branches being lopped off, rising out of the ground with a sweep; its taper diminishing till the sides become perpendicular; and on the insertion of the great boughs, again swells and overhangs.

"*Figure* 2. The manner in which the smaller boughs and branches are obliquely inserted into the greater, with the reconciling curves that form the union.

"*Figure* 3. A specimen of paving to be found in the walking paths of London streets; being a mode of dovetailing in stone.

"*Figure* 4. A sample of stone dovetailing in the upright, taken from Belidor's *Archit. Hydraul.*

"*Figure* 5. A copy of the first complete design made out for the solid courses of the Eddystone. The only material alteration afterwards was to diminish the size and weight of the outward circle of stones.

"*Plate* VI.—*A view of the rock on the east side; and of the work advanced to Course* XV. *the first of the entry-courses; showing the manner of landing and hoisting the stones, &c. in every after-stage of the building.*

"*Figure* 1. The boat Weston in the gut, delivering her cargo.

"P. Q. The two fender piles, to prevent her rubbing against the rock.

"X. The cave, here seen in front.

"D. The gulley, through which a momentary cascade makes its way; and which was proposed to be stopped.

"E F G. The shears; from the head of which are suspended the main tackle-blocks A B, whose tackle-fall, after going to the snatch-block E, passes to the windlass, or jack-roll, whose frame being of iron, is fastened to the rock as per figure.

"The enlarged detached figure *a* shows the frame and roll frontwise, as seen from the snatch-block.

"*b.* The side-view thereof, the roll being seen endwise.

"*c.* The manner of coupling the back-stay to the upright stancheons; and *d* shows, by a figure still more enlarged, the upper end of the stancheons for receiving the gudgeons of the roll.

While the stone is hoisting, the man represented at I is heaving-in the tackle-fall of the runner and tackle H K: for, till the stones are cleared of the boat, the shears lay out considerably, and the out-hawler guy-rope, L M, is slack. This crosses the gut, and is fixed by a ring-bolt to one of the rocks of the south reef. By such time, therefore, as the stone is hoisted by the main tackle to the height of the entry-door, the shears are got into the perpendicular; and then by easing the out-hawler guy-tackle, L N, the stone comes into the entry door.

"The runner and tackle H K is hooked to the guy-chain, O, which crosses the work, and passes down to the ring on the west side of the rock; marked R in *Plate* I.

"In the detached *Figure* 2, the anchor-like piece of iron, by which the main tackle-blocks are hung, is shown to an enlarged scale at *e f g h*. This anchor being suspended upon a round bolt at *e*, that passes through the tops of the two shear legs, swings freely between them, and always putting itself in a perpendicular position, and producing fair bearings upon them, without any unnatural strain or twist, enables them to support the greatest weight possible.

"In like manner the two arms of the anchor *g h*, having the two guy-tackles hooked to them, the action of those tackles is upon the suspending bolt, and the feet of the shears turning freely upon eye-bolts fixed in the rock, they are at liberty to conform themselves to the position wanted; so that the stress upon the legs is always endwise.

"After the building was raised to the height shown *Figure* 1, the work was hoisted through the well-hole, till it arrived at the top of the solid, by means of the triangle and twelve-fold blocks wherewith the work was set; and are shown as standing upon the wall at the first vaulted floor by the letters *i k l m*, being the fourth stage: but after that was completed (the man-hole being too small, and the height too great, without losing time) a jack-roll was established, as shown at the third stage in the lower store-room at Q: and a pair of movable shears, the figure whereof is shown at the fifth stage, as upon the wall, at the kitchen-floor; which, instead of guy-ropes, had a back leg, longer than the rest, whose bottom or foot cut with a notch, stepped upon the internal angle of the opposite wall; and was long enough to suffer them to lean over sufficiently for the stone at P to clear the wall. The shears themselves were prevented from falling over by a luff-tackle, shown upon the back leg, whose lower block hooked upon a lewis, in that stone the back leg stepped upon; by which it was brought tight and steady. When the stone was to be landed, this tackle being a little slacked, till the notch could be disengaged, and then set upon, the back leg would, by going over the wall, suffer the shears to come to the perpendicular, or beyond it.

"The stones, now become in general less weighty, a common tackle was employed at the shear-head, which would go down to the entry door, and there met the stones hoisted by the great shears: the tackle-fall of the movable shears, being taken to the jack-roll Q, the stones were got to the top of the building, in the same time they were raised from the boat to the entry-door.

"The detached figure R is the plan of the movable shears; where the check, or safety rope, *n*, is shown at the foot of the back leg.

"In this manner all the heavy materials were got up; the movable shears rising with the work, till the cupola was to be set upon the lantern.

"The sixth stage shows the apparatus used for this purpose. The great shears being now done with, were taken down and put through the windows of the uppermost room, and there, being well steadied, served as booms. The detached figure S being the plan of this stage, shows their particular disposition; wherein *o p* show the places or feet of the legs of the shears used for this particular purpose; also marked with the same letters in the relative upright. In this, the rope *q r* shows a side-stay to the leg *o r*; and *s t* is the stay of the leg *p t*, each fastened to *q s*, the extremes of the booms.

"From each end of the cross-tree at the head of the shear-poles proceeded the ropes *w x*, *y x*, which, joining in one guy-rope at *x*, proceeds over a pulley in the end of the temporary timber at *z*: from thence, with the intermediation of a tackle, 1, 2, it proceeds to, and fixes at the extreme end of the boom 3; and as the weight to be hoisted will principally lay upon this guy, the stay, or shroud rope, 3, 4, is

passed from thence through the window of the room below, and is there fixed.

"It is now plain, that by the tackle 1, 2, the shears can be let go over as far as necessary, and brought back into the perpendicular; but to counteract this main guy, and keep all steady, the rope 5, 6, 7, with a small tackle upon it, performs the office of an out-hawler guy, fixing to the same ring in the rocks, as that of the main shears had before done. This apparatus enabled the cupola to be hoisted and set on whole without a bruise.

"*Plate* VII.—*Plan and description of the work-yard at Mill-Bay, with its furniture and utensils.*

"*Figure* 1. The general plan of Mill-Bay, wherein the dotted line *a b c* shows the line of low-water spring tides.

"*d e*. The channel dug from low water to convey vessels to the head of the jetty *f g*.

"*h i k l*. The area of the work-yard.

"Since the removal of this work, has been built I. the long room.

"A C. The marine barracks.

"D D. New streets of Stonehouse.

"*Figure* 2. Plan of the work-yard and jetty. A B C D, the line terminating the head of the channel. Now any vessel lying against the two large piles B C, on which a pair of shears being erected, can be unloaded of her cargo of stone, and delivered upon a wheel-carriage; that passing along the jetty to the turn-rail E, the carriage is there turned round till it becomes fair with the rail-road E F; and passing along it, enters the work-yard, whose boundary is marked by G G G G.

"At T is another turn-rail, which enables the carriage to go on with its burden; either in the straight line, or to turn there and go along the rail-road in the middle of the yard, and arriving at any destined point, suppose H, it is there met by a roll-carriage; for which, planks being temporarily laid, as at I, the burden (being transferred on small rollers) will be easily moved thereon to the extremity of the yard sideways; and thus stones can be deposited, as at K K (shown edgewise upward) upon any point of the area of the yard, and returned by the same means.

"The area bounded by the line G G, and the dotted line L L, is the Portland workshed.

"M denotes one of the bankers; to which, from the wheel-carriage (supposed on the rail-road opposite) strong joists being laid, as shown by the dotted lines, the pieces of stone are brought on small rolls; the bankers having notches sunk therein, to receive the ends of the joists.

"In like manner, the area N O was the shed for the moorstone workers.

"The square area P Q denotes the extent of a roof, supported by four posts, covering the platform; whereof *a b* represents the platings of rough stone walls; *c d* one of its principal floor timbers, 6 by 12; these being covered with three-inch planks, and brought to a true level, made a stout floor, upon which the courses were brought together.

"R. The cabin for the foreman of the yard.

"S. A small store-room for tools and iron-work.

"G W. The store-shed for Watchet lime and puzzolana.

"V X. The shed for bucking or beating the larger parts of the puzzolana upon W Y, the bank with three cast-iron beds upon it.

"*Figure* 3. Supposed a detached figure, being the ground-plan of the turn-rail at T (*Figure* 2) to an enlarged scale, wherein A B is a dormant circle of wood well supported; of which C marks the centre-pin fixed in the transverse beam D D: E E being connected studs.

"F F. Portions of the rails, whereon the wheels move, which are kept in place by the fillets *f f*, nailed on each side.

"G G. The sleepers for supporting the rails at about a yard's distance middle and middle; as is also shown near E, in *Figure* 2.

"*Figure* 4. The plan of the movable turn-rail, and *Figure* 5 the relative upright; shewing also the section of the dormant circle. The three last figures having a mutual reference, the same parts are marked with the same letters: and furthermore, in *Figure* 4 and 5.

"H I. The rail part of the turn-rail, correspondent to those parts marked F F, *Figure* 3, in width and height. The rail parts, H I, are strongly framed upon the cross beam K K, and connected by the pieces L L. The whole being poised, with its burden, upon the pin C, but without absolutely touching the dormant circle A B while turning; for bearing only upon the flat shoulder of the pin, it turns easily; but, when it is bringing on, or wheeling off, the equilibrium upon the pin being destroyed, the ends, H, I, are then supported upon the dormant circle, and the wheels will move steady.

"*Figure* 7 shows the plan, and *Figure* 8 the upright view of the wheel-carriage, to the same scale as that of *Figures* 3, 4, and 5. Also *Figure* 9, and *Figure* 10, give the upright views of the roll-carriage in two directions, to the same scale; which show distinctly the manner of supporting the axis of the rolls on iron frames; and how the iron frames are kept upright by four pair of cross bars.

"*Figure* 11. The upright of the capstan-roll, axis, and middle part of the bar to the same scale. At 1, 2, is shown the capstan in full, to the scale of the yard; and 3, 4, and 5, mark the direction of the rope, which, from a snatch-block at 5, ascends to the upper block of the main tackle, suspended from the top of the shears, as per *Figure* 6, wherein the in-hauler guy-tackle is marked 7, being a runner and tackle; and the out-hauler, marked 8, are simple blocks. The guy-rope, 7, 6, was attached to a ring-bolt, passing through a large rough stone, rammed into the ground; its place being shown at 6, (*Figure* 2,) the out-hauler guy 8, 9, being secured in the same manner.

"The marble rocks, marked 10, go round the point of the bay.

"*Figure* 12. The elevation of the upper part of the jetty-head in front, with the shears upon it, to an enlarged scale; more particularly to show the smaller parts.

"A, B. The front pair of piles, to which the cross-beam C D is bolted, and, in like manner, to each pair of piles.

"E, E. The ends of the longitudinal half balks.

"F F. The cross joists.

"G, G. The ends of the flat rails that the wheels of the carriage run upon.

"H H. A single cross timber, serving as a stop to the carriage at the end.

"I. The snatch-block.

"*N. B.* The scantlings are marked, because this jetty or scaffold, erected as slight as possible for a temporary purpose, sustained the whole tonnage of the Eddystone matter, in and out, without derangement.

"The detached *Figure* 13, gives a part of the top of one of the shear legs, showing how they were plated on each side to support the bolt of the anchor from bending, and thereby from splitting the poles.

"*Figure* 14. The enlarged figure of the runner and tackle (marked 7, in *Figure* 6.)

"K. The runner-block of one large single pulley.

"L M. The tackle-blocks, of three pulleys each, making a purchase of twelve, equivalent to the great blocks.

"*Figure* 15. An upright diagonal view of the main-tackle blocks; having six pulleys each upon two pins; the larger tier being ten, and the lesser eight inches diameter. This

figure distinctly shows the method of salvagee strapping; being double, that the pins being readily knocked out, they could be frequently greased without trouble.

"*N. B.* The shears, blocks, and tackles, used at Mill Bay, were nearly the same as at the rock; and one pair of main tackle blocks at each place, with the same pulleys, went through the whole service; but the pins were renewed each season, and sometimes oftener, being of wood, on account of the salt-water; but were frequently greased. The main tackle-fall at each place was no larger a rope than of three inches circumference; being a white rope, remarkably soft laid, hauser-fashion; and which is of material consequence.

"*Plate* VIII.—*Descriptions of supplemental matters, having reference to the Eddystone building.*

"*Figure* 1. An upright front view of the great tackle, or purchase-blocks of twenty sheaves, or pulleys.

"*Figure* 2. A side view of the same blocks, referring to *Figure* 1. The advantage of this construction is, that the tackle-fall, or running-rope, may be reeved through the twenty sheaves, without a cross or interference; so that the standing part, or beginning, may be in the middle of the upper block: and the ending, hauling part, or fall, upon the middle pulley of the same block. The weight therefore being suspended by twenty ropes instead of six, as in common triple-blocks, the tackle-fall, as relative to a given weight, may be lesser or of fewer yarns in the same proportion; which renders the whole much more flexible and pliant, and which, together with the advantage derived from the mode of reeving, occasions their rising and falling nearly upon a parallel. Beginning in the middle, the greater sheaves are reeved as far as can be on them; from thence going to the first of the smaller sheaves, and reeving the whole of them throughout, you then go to the first of the greater sheaves, before left unreeved, ending upon the middle sheave of the upper block; and thus arises a diminution of the friction from the more equal distribution thereof.

"*Figure* 3. An upright section of the store-room, to an enlarged scale; in it is shown the centre whereon the upper store-room floor was turned; and in like manner the rest.

"*Figure* 4. The plan relative thereto, the letters being common to both.

"*a b, c d.* Two of the sixteen ribs, formed to the circle of the vaults of the floors. These ribs are connected at their ends by two wooden rings, *e f, g h i k;* the former supported by four posts, three of which are shown in their places, and the latter by eight; of which only one is shown on the right hand, and one on the left, to avoid confusion. The rings are each made to take asunder, that after striking the centre they might be got out of the room.

"At *l l, m m,* two of the ribs are supposed taken out, to show their bearings upon the rings; they were open centres, that it might be seen underneath when the joints were fair.

"*Figure* 7, of *Plate* IV., shows how the sixteen radii of stones would apply to the sixteen ribs. In this plan, *Figure* 4, A shows the well-hole, and B B the cross timbers for supporting the four middle posts, whose places are marked out by dotted little squares.

"*Figure* 5. An elevation, and *Figure* 6, the relative plan of a dial stone, taken professedly from the general figure of the Eddystone lighthouse; being the design of the late James, Duke of Queensberry, and by him erected at Amesbury, Wilts, with a dial upon it, by Mr. Ramsden. The drawing, of which this is a copy, was given me by the Duke; and is placed here as an instance, that the Eddystone column may be applied to some uses of architecture.

"*Figure* 7. One of the silver medals given to the seamen as a token of the service.

"*Figure* 8. The tool wherewith the stones were got up from the bottom of the gut.

"A. One of the stones with two trenail holes.

"Suppose this stone lying flat in the bottom of the gut, the side A uppermost. The tool has a pole or staff, *b b*, about twelve feet long, sufficient to reach the bottom. This single prong, *c*, is forged to a very single taper, such as to be thrust eight or nine inches into a trenail hole, (all of them being bored to a gauge) it can be driven by the pole, till fast; observing that the arm *e* corresponds to the centre of gravity of the stone. The water is generally so clear as to see to the bottom; and, in case of any ruffle by the wind, can be in a great measure freed from agitation, by looking through a speaking trumpet, whose mouth is put down eight or ten inches into the water. The rope *d e f* being then set upon by the main tackle, instead of its drawing out, the length of the arm *g* causes the prong to jamb the faster in the hole; and the staff being quitted by the hand, with a cord to hinder its flying off too far, the whole assumes the position of the figure; and, when brought above water, is lowered into a yawl.

"*Figure* 9. A section of one of the mortar buckets, and in it the beater.

"*Figure* 10. One of the internal faces of the lantern's glass frames, and therein the cross bars of iron, as they were actually fixed. Besides the flat at each end of each bar, distinguished by a darker shade, and through which the screws passed; each end was also cranked about an inch, so as to set the transverse part of the bars clear of the copper sash-frame; and they were cleared of each other at their intersection, by one of them being made straight, the other curved in that part. All the panes being taller than the candles, the chandelier rings are so hung, that when the candles are at rest, dispensing their light, that of one chandelier passes through the range of panes A, and that of the other through the range B; and when the candles are snuffed, one of the rings of lights being seen through the range C, the other mounts to D, and *vice versa.*

"*Figure* 11. The chain of triangles from the Eddystone to the flag-staff of the garrison of Plymouth, for ascertaining their distance trigonometrically.

"*Figure* 12. An enlargement of the work within the headlands of the Sound.

"The whole country about Plymouth Sound being very uneven, I could not readily obtain a base better, than by very carefully measuring the two lines B G, B W, taking the intercepted angle W B G; whence the right line W G was obtained, making a base of 1871 feet, and which I cannot suppose to err more than half a foot. Again, the nearest place from whence the two beacons, W, G, could be commodiously seen for the purpose, was the point S; and all the three angles of the triangle W S G, being likewise carefully taken, I conclude the angle W S G $= 10° 23'$, taken true to a minute; that is, to $\frac{1}{623}$d part of the whole angle. The line S W could therefore be determined within $\frac{1}{623}$d part; which being considered as a new base of larger extent, may be esteemed true within $\frac{1}{600}$th part of the whole. From this, and the angles taken as marked upon the scheme, the lines W P, W M, and W E, were successively determined; and finally F E, the distance of the flag-staff from the Eddystone, came out very near, but somewhat less, than fourteen miles. But the interior harbour of Plymouth, called Sutton Pool, being about three furlongs farther from the Eddystone, than the flag-staff, the whole distance may be esteemed fourteen miles and a quarter from Plymouth harbour."

Thus was completed the Eddystone Lighthouse, which must ever be considered a masterpiece of its kind. The merit of utility is not its only characteristic; but in beauty, as well as in strength and originality, it deserves the highest amdiration. And when we remember the extraordinary difficulties by which a work like this must have been surrounded, we must own, that had its contractor left no other memento of his genius, the Eddystone alone would be sufficient to immortalize the name of Smeaton.

EDGE, the intersection of the two planes or surfaces of a solid, which is consequently either straight or curved according to the direction of the surfaces. *See* ARRIS.

EDGE is also that side of a rectangular prismatic body, which contains the length and thickness, but in this sense of the term, the body to which it applies is generally understood to be very thin; thus we say, "the edge of a door," the "edge of a board," meaning the narrow side.

EDGE OF A TOOL, the meeting of the surfaces when ground to a very acute angle.

EDGE-TOOLS, all those which chip or shave in the operation of working.

EDGING, in carpentry, the reducing of the edge of ribs or rafters, whether externally or internally, so as to range in a plane, or in any curved surface required; backing is a particular case of edging, and only applies to the outer edges of ribs or rafters, but edging, or ranging, is a general term, and applies indifferently, either to the backing or internal surface. *See the terms* BACKING and RANGING.

EDIFICE, (from the Latin, *ædificium,*) a building constructed either for use or ornament. The word is not usually applied to a mean or inferior building, but to temples, churches, or elegant mansions, and to other great structures. *See* BUILDING, HOUSE, TEMPLE, &c.

EDILE, (Latin, *ædilis*, from *ædes*, a building,) an officer in ancient Rome, whose business was to superintend buildings of all kinds, more especially those of a public character, as temples, aqueducts, bridges, &c.

EFFIGY, a representation or likeness of anything, the term being particularly applied to sculptured representations of human figures. Such effigies were very common on tombs erected from the fourteenth to the sixteenth centuries, and were of various materials, stone, marble, alabaster, and even of the precious metals.

EGGS, ornaments in the form of oblong spheroids having their greater axis inclined, projecting at the top and receding at the bottom, but each axis in a plane perpendicular to the surface of the ovolo. In straight mouldings, all the axes will be in the same plane; but in annular mouldings or those generated round an axis, all the axes of the spheroids will be in the surface of a cone, whose vertex will be downwards, and will terminate in the apex. The eggs are most generally truncated, or have their upper part cut off by a plane parallel to the horizon. *See* ECHINUS.

EGYPTIAN ARCHITECTURE. The character of the Egyptians, as developed in early history, would naturally lead us to suppose, that an inquiry into their style and manner of building would form a subject for interesting study, not only to the antiquary, but also to all such as take any interest in general history; and such doubtless is the case. The history of the place attaches an unusual interest to everything connected with it. Of the early history of Egypt, like that of the other primæval nations we know but little for certain, all narrative dating back beyond a certain period, having an air of mystery about it, which it is not easy to penetrate, and this fact is more especially true, as regards the origin of nations. If we believe the records of the Egyptian priests, as handed down to us by Herodotus, Manetho, Eratosthenes, and others, we shall have to carry back the date of its origin far beyond the period generally assigned as the commencement of history. Manetho gives us a series of dynasties upon dynasties, which, if successive, reach beyond the bounds of time; to obviate which difficulty, it has been suggested, that they were not all successive, but several contemporaneous, reigning over different parts of the country; but, indeed, the whole matter would seem to be fabulous, for in the same place is related the gigantic stature of several kings, their wonderful exploits, and other circumstances characteristic of mystical and confused tradition. The first king alluded to by historians is Menes or Men, who is supposed to have lived above 2,000 years B.C., about the time of the foundation of Assyria by Nimrod, and of the reign of the Chinese emperor Yao, with whom the historical period of China begins. It is doubtful which of these nations came first into existence; we are inclined to give the preference to the Assyrians, but whichever takes the lead, there was probably but little difference between them in point of time. It is certain that Egypt stood out pre-eminent in civilization, and that, too, at a very early period; its success in the cultivation of the arts, and in the pursuit of science, was greater than that of any contemporaneous people, as is evident from their remains to be seen at the present day. At the close of Manetho's sixteenth dynasty, the irruption of the Hyksos, or shepherds, is supposed to have taken place; his seventeenth dynasty consisting of shepherd-kings, from which period it is alleged that the erection of the existing edifices must commence, all the previously existing buildings having been destroyed by the shepherds. As a proof of this, is adduced the circumstance, that at Carnac, and other of the oldest monuments of Thebes, sculptures and painted stones, of good workmanship, are to be found, used as mere materials in the body of the walls.

Besides the ancient authors already mentioned, we have Strabo and Diodorus Siculus, who have given some account of Egypt and its buildings, and to these we shall have to refer occasionally as we proceed.

In turning to modern writers on this subject, we shall find but few who enter fully into the subject previous to the commencement of the present century, little or nothing having been known of Egyptian buildings unless it were of the Pyramids, until the French expedition, at the close of the last century; no satisfactory delineations of the temples, or their details, had been taken, but only such sketches as were calculated to convey some general idea of their characteristic massiveness. To Denon, and the contributors to the great French work on this subject, we are principally indebted for our present information. Pococke and Norden have treated somewhat largely on their researches in this country, but their remarks are too general and too loose to be of much service. Denon had advantages unattainable by any of his predecessors; independent of his own high qualifications, his efforts were seconded by the able assistance of men of talent, sent out for the purpose, themselves well fitted for the task. Besides these, we may mention Belzoni and Champollion; and, amongst our own countrymen, Savary and Wilkinson.

According to Manetho's account, the temples to which the remains described by Denon belong, were erected by the first dynasties of the Pharaohs, or about 2,200 before Christ: these first structures, however, were destroyed by the invading shepherds, as before noticed. These usurpers were, in turn, driven out by the Pharaohs, who were restored to their throne about 2,000 years B.C., and thereupon set about rebuilding the temples, the remains of which are seen at this day.

The character of Egyptian architecture is that of massy grandeur and severe simplicity, as exhibited in the simple,

well-defined outline, and in the colossal dimensions of their temples, and the immense blocks of material employed in their construction. The great object of the builders seems to have been, that the strength and durability portrayed in the prodigious magnitude of their structures should serve to typify their own greatness. They did not consider, when they were erecting their temples, that they were building them for an age, but for eternity; nor, comparatively speaking, were they deceived in the estimate of their works; for now, after the lapse of three or four thousands of years, we have some portions which are likely to last as many more centuries, unless wantonly destroyed by the hand of man. Had, indeed, the buildings only to contend with the ravages of time, we should have many a structure perfect, where it is now a heap of ruins; had it not been for the reckless destruction of these wonderful monuments by Cambyses, it is questionable whether they would not all have been entire at the present day, and certainly in a better state of preservation than many modern buildings which have not numbered as many ten years as the former have centuries. Even now, the carving, and, in some instances, paintings, to be seen in the ruins, are as fresh and bright as if only just executed.

The immense size of the stones employed, and the mechanical art necessary for transporting them from the quarry, and afterwards raising them to the required elevation in the temples, when building, cause these sacred structures to appear like works of superhuman labour. In every degree, they exhibited a solemn majesty of style, and imposing grandeur; while austere simplicity, combined with order, uniformity, and regularity, pervade the whole design.

This, with the solidity and massiveness of the parts, and the prodigious dimensions of the stones, imparted an air of the most impressive and awful sublimity on the mind of the beholder.

Belzoni, who visited Egypt, observes, in his enthusiastic manner, when entering this magnificent temple—"I was lost in a mass of colossal objects, every one of which was more than sufficient of itself to attract my attention; I seemed alone in the midst of all that is most sacred in the world; a forest of enormous columns, adorned all round with beautiful figures, and various ornaments, from top to bottom; the graceful shape of the lotus, which forms the bell-shaped capitals, and which is so well-proportioned to the columns; the friezes, also adorned in every part with symbolical figures in low relief, representing battles, processions, triumphs, priests, and sacrifices; all relating to the ancient history of the country. The walls of the sanctuary, usually formed of red porphyry granite; the high portal, seen at a distance from the openings of this vast labyrinth of sacred edifices on each side of me, had such an effect upon my soul as to separate me in imagination from the rest of mortals, exalt me on high above all, and cause me to forget entirely the trifles and follies of life!" "It further appears," he says, on entering the city of Thebes, "like entering a city of giants, who, after a long conflict, were all destroyed, leaving ruins of their various temples as the only proof of their former existence." Champollion exclaims of Carnac, "These porticos must be the work of men one hundred feet in height;" and Denon adds, "Such structures appear like dreams, or the works of giants!"

Of the impression made upon the mind of Denon by these stupendous structures we have sufficient evidence in his work on the subject; the few following passages have been selected from a multitude of a similar kind.

Of the portico of Hermopolis, he says, "This was the first monument which gave me an idea of the ancient Egyptian architecuure, the first stones that I had seen which had preserved their original distinction without being altered or deformed, and had remained there for four thousand years; here I fancied I saw engraven on every stone the words Posterity—Eternity. It gave an idea of the immense range and high perfection to which the arts had arrived in this country. If a peasant should be drawn out from his mud-cottage, and placed before such an edifice as this, would he not believe that there must exist a wide difference between himself and the beings who were able to construct it, and, without any idea of architecture, would he not say, 'This is the work of a god; a man could not dare to do it, or inhabit it.'"

This is his first impression, nor is his admiration less apparent at the close of his researches; novelty may excite wonder and interest, but merit alone can maintain them. At a later period, the description of Tentyra calls forth the following remarks:—

"Nothing is more simple and better put together than the few lines which compose this architecture. The Egyptians borrowing nothing from the styles of other nations, have here added no foreign ornament, no superfluity of materials: order and simplicity are the principles which they have followed and they have carried them to sublimity. At this point they have stopped, and have attached so much importance to preserving the unity of design, that though they have loaded the walls of these edifices with bas-reliefs, inscriptions, historical and scientific representations, none of these rich additions intersects a single line of the general plan, all of which are religiously preserved unbroken; the sumptuous decorations which appear to the eye when close to the building, all vanish at a short distance, and leave full to view the grand elements of architectural composition which are dictated by sound reason. It never rains in this climate, all that is wanted therefore is a covering of platbands to give shade, but beyond this neither roof nor pen diment are added; the plain-slope is the principle of solidity; they have therefore adopted this form for every main supporter, doubtless with the idea that stability is the first impression that architecture should give, and is an essential constituent of this art. With these people the idea of the immortality of the Deity is presented by the eternity of his temple; these ornaments, which are always rational, always consistent, always significant, demonstrate a steadiness of principle, a taste founded upon truth and a deep train of reasoning; and if we even had not a full conviction of the eminent height to which they had attained in the abstract sciences, their architecture alone, in the state in which we now find it, would give the observer of the present day a high opinion of the antiquity of this nation, of its cultivation, and the impressive gravity of its character."

Of Carnac he at last exclaims—"One is fatigued to describe, and to read, and to think, of such a conception; after having seen it, one can hardly credit the reality of the existence of so many structures collected in one spot, of their size, of the determined resolution (*constance obstinée*) which exacted their erection, and of the incalculable expense of such magnificence."

Of the æsthetic character of Egyptian architecture, our author observes:—"These monuments, (Tentyra,) which imprinted on the mind the respect due to a sanctuary of the divinity, were the open volumes in which science was unfolded, morality dictated, and the useful arts promulgated; everything spoke, every object was animated with the same mind. The opening of the doors, the angles the most private recess, still presented a lesson, a precept of admirable harmony; and the lightest ornament on the gravest feature of the architecture, revealed under living images the abstract truths of astronomy."

"Painting added a further charm to sculpture and architecture, and produced at the same time an agreeable richness, which did not injure either the general simplicity or the gravity of the whole. To all appearance, painting in Egypt was then only an auxiliary ornament, and not a particular art; the sculpture was emblematical, and, if I may so call it, architectural.

"Architecture was therefore the great art, or that which was dictated by utility, and we may from this circumstance alone infer the priority, or at least the superior excellence, of the Egyptian over the Indian art, since the former, borrowing nothing from the latter, has become the basis of all that is the subject of admiration in modern art, and what we have considered as exclusively belonging to architecture, the three Greek orders, the Doric, Ionic, and Corinthian. We should therefore be cautious of entertaining the false idea which is so prevalent, that the Egyptian architecture is the infancy of this art, since it is, in fact, the complete type."

Such is the universal and oft-repeated admiration of modern travellers: had such expressions been used by an ancient author, and the buildings now demolished, we should have been apt to treat the matter as purely fabulous, but now they are undoubted realities, and stand as evidence of the truth of history. Such structures could doubtless have been erected solely under a despotic government, and probably, for the most part, by captives or slaves, and not by free Egyptians, as we read of the Israelites in the time of Moses being tasked in this manner; the manual labour employed on such structures must have been enormous. It is a matter of the greatest wonder how such immense masses of material were transported from the quarries, and fixed so accurately in their respective places; even in the present day, with all the advantages of machinery and steam-power which we possess, the erection of such structures as those of Egypt would be considered no light undertaking. Notwithstanding the vast magnitude of these erections, they were remarkable not only for their size, but no less for their enrichment; ornamentation of various kinds was lavishly distributed over the whole surface. It is true, the buildings appear to greatest advantage when exhibited as a whole, yet each minute portion will bear, nay, require, minute examination; a close inspection reveals the most elaborate enrichment, while a distant view exhibits the noble outline and the grander features of architectural composition.

No two styles would at first sight appear more dissimilar, more antagonistic, than the Egyptian and Gothic, the one ponderous and massive, the other light and elegant; the one flat, of low proportions, and presenting a great extent of unbroken horizontal lines, the other slender, lofty, and aspiring. What contrarieties do they present! and yet we shall find that they have many characteristics in common, not indeed in their architectural features, but in the æsthetic principles followed out in their construction and decoration. The temples of the Egyptians were but the embodiment of their religion; their massive proportions typified the greatness, as the continuity of the outline and repetition of parts illustrated the eternity and immutability of their deity. Their objects of worship inspired feelings of profound awe, so likewise did their temples. Nor were their decorations merely the result of caprice, but of studied design; every detail was subservient to some great end, and suggested by some urgent reason; they all have a symbolical meaning, illustrative of the Divine attributes, and consist, in short, of a series of religious dogmas and precepts, embodied as it were in forms. They were, as is said of the pictorial and carved enrichment of Gothic edifices, the books of the unlearned, each object speaking more intelligibly and more impressively to the eye and mind of the beholder, than would whole volumes of written precepts.

"The materialism of Egyptian worship," says a writer on this subject, "rendered all these details essential; it fixed the imagination on physical nature, and obliged the ecclesiastics to seek those forms best calculated to express the dogmas of their religion. And in contemplating their architecture, it is impossible not to be struck with the manifest influence religion has had in its creation." In allusion to another similarity as regards the circumstances connected with the erection of Egyptian and Gothic edifices, he says, "The priests, who were the great depositories of all knowledge, were the exclusive designers of their religious edifices; they alone directed the taste of the architect and the sculptor; and they employed architectural grandeur, with all its accessories, to influence the minds of those people whose actions they wished to govern; nor can I imagine anything better suited to inspire religious awe, and a profound reverence for the divinity, as well as his earthly agents amongst an idolatrous people, than this style of architecture." In passing, we may remark upon another affinity between the two styles, which approaches more nearly to an architectural characteristic, and that is, the practice of copying nature, all the decorative details of Egyptian, as of Gothic architecture, being the most beautiful imitations of the natural productions of their country—the lotus, palm, reed, papyrus, &c.

Having thus given a description of the general character of this style of architecture, it will be as well to proceed at once to the consideration of the buildings more in detail, as regards plan, distribution, and arrangement of parts, method of construction, and such like; in doing which we shall take as an illustration the temple at Edfou, or Apollinopolis Magna, one of the largest in Egypt.

The size of this temple is much more comprehensive, and its arrangement much more complicated than that of Greeian structures, for whereas the latter consisted of a single cell surrounded by a wall with external columns, the former was composed of several courts, one within and beyond the other, and having columns for the most part within the walls. The entrance to the whole building was through a door placed between, and somewhat in advance of two enormous pyramidal towers, termed propylæa, which rose considerably above the general mass of the building, and were covered on the sides with sculptured figures of colossal size. The plan of each pyramid in this case measures 104 feet in length and 37 feet in width at the base, the dimensions diminishing gradually to the summit, where they are 84 feet by 20 feet, the heihgt being about 150 feet. Each mole is finished by a projecting cornice, and is surrounded on all sides by a bold torus moulding. They may be considered as solid structures, for although they contain chambers with their approaches, still these bear so small a proportion to the entire mass, that they amount to no more than small voids or cavities. The colossal entrance between the pyramids is crowned with a cornice, and finished at the angles with a torus-moulding similar to the propylæa, and was probably furnished with folding doors, as the notches for hinges are still visible. This door-way gave admission into a peristyle court having twelve columns on either side, and four on either side of the entrance at a little distance from the propylæa. The pillars at the sides are placed at some distance from a wall, which commences at the moles and surrounds the entire temple, and the space between this wall and the columns is roofed over, so as to form a covered-way or piazza, which leads on either side to the doors of the staircases in the propylæa, and is continued in a similar manner in front of them, on the entrance-side of the area. The colonnade throughout is picnostyle, which seems to have been the

usual disposition, the intercolumn being seldom greater than a diameter and a half, except in the centre of a portico, where a doorway intervened, which practice is identical with that of the Greeks, as evinced in the Doric order. The height of the colonnade from the base of the columns to the top of the projecting cornice, with which they were surmounted, is about 38 feet. This court is not level, but has a considerable ascent towards the farthest side, which is effected by a series of low and very wide steps, extending the whole width of the quadrangle, and commencing at its entrance. The width of each step is that of a column and intercolumn, and the total rise is 56 feet. This alteration of level seems to have been introduced for the purpose of giving elevation to the grand portico which forms the farther side of the court, and consists of eighteen columns, in three rows of six each, placed one behind the other, and flanked on either side by a wall so as to resemble a Greek hexastyle in antis, with the exception that here there are three parallel rows one behind the other, while in Grecian temples there are never more than two. The portico, however, bears a greater resemblance to the propylæa of the Greeks, than to their temples, both being open in front, and enclosed on their other sides, having several rows of columns one behind the other. The columns in this portico, or pronaos, are loftier than those in the court below, and are surmounted like them with a projecting cornice. The spaces between the front row of columns are filled up to about half their height with a screen or dado, which gives the upper part of the intercolumn the appearance of a window. The middle intercolumn is treated in a somewhat different manner, the wall or screen being carried up somewhat higher, and advanced a little in front of the general line; the sides likewise being flanked with short columns, and the entrance to the pronaos being cut through the screen. In the wall at the further end of this first hall, is an entrance into a second of smaller dimensions, a space being taken off each side for passages. This hall is hypostyle, covered with a flat roof composed of thick slabs of stone, resting on large stone beams, which are supported again by twelve columns disposed in three rows of four each, closely set, so as to leave only narrow passages between them. From this hall we come into a chamber, having its greatest length in the width of the building, as also has the portico, and having entrances to the passages at the side of this chamber, and the hypostyle hall, from which access is obtained by means of steps to the top of the *sekos*. Beyond this is another similar chamber of smaller dimensions, having a cell on either side, supposed to have been for the priests. Entrance is obtained from this chamber into the sanctuary, which is a small covered chamber having its greatest length parallel with that of the main building; its size is about 33 feet by 17, and in it was placed the image of the deity. Round the two sides and further end of the sanctuary, is a passage, to which access is obtained from the second chamber, and round this again a larger area of similar shape, into which the smaller one led, and which gave access to the top of the sanctuary. In most instances, in front of the whole building, and a short distance in advance of the propylæa, were erected two obelisks of great height, and covered with hieroglyphics, and in front of them a long avenue, or *dromos*, as it is called, formed by two rows of sphinxes, placed at short intervals from each other, the space between the two rows forming a way or road to the temple. Strabo, the historian, who saw this temple we have been describing, alludes to this avenue—"Before the pillars or propylæa," says he, "is a paved road or avenue about 100 feet in breadth, or sometimes less, and in length from the entrance from 300 to 400 feet, or even more. This is called the dromos; through the whole length of which, and on each side of it, sphinxes are regularly placed at the distance of 30 feet from each other, which forms a double row on each side. Between the sphinxes you advance towards the temple, until you come to a large propylæum or triumphal entrance, through which you pass; and as you advance, you come to another propylæum, which you pass through; then to a third; and still keep passing on until you come to the entrance into the temple."

The above description, although of a particular example, will answer with but little alteration for any other temple, all such buildings being built on a similar plan, with but slight variations in particular instances. They all consist of a *sekos*, or sanctuary, of small dimensions, situate near one extremity of the building, surrounded on all sides with chambers, passages, and courts, and approached through a series of covered halls and colonnaded atria, the whole of the buildings being inclosed within an outer wall, and having a grand entrance flanked by two pyramidal moles. No matter to what date a building may belong, or what position it may occupy, the general form is the same, the only difference being in the size, and in the number of adjoining courts and buildings. In some cases, we have two or more propylæa, and courts preceding the temple, and sometimes avenues of columns crossing the courts in a line from the entrance. The temple at Luxor has as many as three courts, the first with a double peristyle, the second with a double range of columns extending throughout its length, and the third flanked by colonnades, each consisting of a double row of columns. To give some idea of the magnitude of this work, we may add, that in the second court, the columns were 56 feet high, and 11½ feet in diameter.

We now pass on to consider the elevation of such buildings more in detail. The contour of the elevation was pyramidal throughout; not only did the obelisks and propylæa present this appearance, but even the walls, spreading out at the base, and converging towards the apex, and as these formed the external face of the building, they gave the whole a pyramidal appearance, which doubtless adds considerably to the expression of strength, which is a marked characteristic of the style. The columns are the only parts of the building in which this form is not observable, their profile being for the most part vertical. This is just the reverse of Grecian architecture; for there the walls are vertical, and the columns sloping or conical, the general effect, however, is the same—pyramidal; for whereas in the Grecian buildings, the sloping columns are placed on the exterior, in those of Egypt the walls are external, surrounding the upright columns, so that the profile of the building, taken as a whole, is the same, although the arrangement is reversed.

An Egyptian order—if we may so apply the term—consists, like the Greek, of column and entablature, which parts we proceed to consider separately. Existing remains offer us examples of columns in great variety, differing in shape, proportions, and decoration, a few specimens only of which we can pretend to notice. The diversity observable in them is so great, that it would be futile to attempt a detailed classification; for examples which present similarities of form or decoration, differ in proportions, while those agreeing in the latter vary in many other particulars. As in other styles, the column consists of three members, base, shaft, and capital: the first, however, can scarcely be termed a distinct member, being in some cases scarcely recognizable, and in none forming a very prominent feature. It is usually a plain circular slab of stone or plinth, sometimes projecting from and at others flush with the face of the shaft, or of the same projection as the widest or bulging portion of the shaft, and

projecting forwards somewhat at their junction, where the shaft curves inwards.

The shafts present many variations, both in contour and decoration; their most usual form is that of a cylinder, or more nearly approaching the cylindrical than any other figure, there being frequently a slight difference between the upper and lower diameters. Sometimes the shaft contracted suddenly immediately above the base, the contour of this portion being curvilinear, and forming a tangent with the upper surface of the base, resembling in shape the calyx of a flower, the similarity to which is made the more remarkable by the leaves carved upon its surface. This last form can scarcely be recommended for its beauty; for in spite of the assertions of its admirers, it certainly does present an appearance of weakness. It is said that in such cases the judgment comes to the assistance of the senses, and corrects the eye, and that what is well known to be strong, cannot fairly be said to appear weak, and this is doubtless true to a certain extent; nevertheless, speaking abstractedly and artistically, this form is decidedly objectionable. In some instances, the columns slope downwards in a slight degree, similar to those of Greece. The cylindrical shafts are usually reeded, giving the surface the appearance of a number of staves or reeds placed round a common centre, or of a bundle of reeds, whence this kind of column has obtained the name of the *bundle pillar*. This resemblance is borne out by the fact, that such shafts are usually cinctured at intervals by bands consisting of three or more rings, which gives one the idea of a bundle of reeds bound round with reeds or rushes to preserve them in their position. These bands are sometimes of greater width, and have a plain surface, or one of the intervals between two bands is left blank, which again is often filled up with hieroglyphics or other ornaments. Specimens of reeded shafts of the different descriptions mentioned, are to be found at Beni-hassan, Hermontis, and Latopolis, and indeed in almost every locality; they are more prevalent than any other form. At other times, the reeds entirely disappear, the plain shaft being divided vertically into a number of compartments as before, by means of annulets or bands of reeds, and these compartments filled in with hieroglyphics; many elaborate examples of this kind are to be seen at Dendera.

Although cylindrical shafts are by far the most general, yet we occasionally meet with examples of a polygonal form, and sometimes with plain rectangular piers; a remarkable instance of the former exists at a temple at Eilethyas, on the right bank of the Nile, a few miles south of Esneh, where, in the interior of a large vestibule, the whole of the roof, as Mr. Barry informs us, is supported on polygonal columns of sixteen sides. Examples of the rectangular piers are described by the same writer as existing at Beni-hassan.

Instances of the employment of Caryatid figures in the place of columns are not unfrequent, they are placed in front of square piers, and do not bear the whole weight of the superincumbent mass, whic his mainly supported by the piers. Examples of this kind are to be found at Ramesseion, Thebes, and Ibsambal, on the banks of the Nile, between Egypt and Ethiopia. The pronaos of the last-named temple, according to Belzoni, is 57 feet long and 52 wide, supported by two rows of square pillars, each having a figure of Sesostris attached to it about 30 feet high, finely executed, and in good preservation. The pillars are five and a half feet square, and the sides are covered with hieroglyphics.

Of capitals, Egyptian architecture affords a vast variety, widely differing in form and character. One prevailing form is the bulging or bulbous capital, which projects from the shaft in a flat curve, but, instead of continuing to expand as it proceeds upwards, it recedes back, gradually diminishing in thickness, until at its junction with the abacus its diameter equals that of the shaft; the contour is similar to that which would be produced by a slightly yielding body pressed down by a superincumbent weight. Sometimes this capital exhibits a plain surface, only relieved by hieroglyphics arranged in horizontal rings, as at Kournon; at others, it is divided into eight or more compartments, or shafts, running vertically from top to bottom, and covered with hieroglyphics, or reeded, in which latter case another subdivision of shafts frequently takes place about half way up the capital, or the shafts are interrupted by one or more horizontal bands, either plain or covered with hieroglyphics, as at Latopolis. The simplest capital of this kind is where the reeds of the shaft are carried up without any interruption, with the exception of a band at the top of the shaft, underneath the bulge of the capital.

Another form of capital, which was frequently adopted, is the bell-shaped, resembling, in contour, an inverted bell, and covered with leaves, flowers, &c., or they may be said to resemble the bell and petals of a flower, the upper rim turning over, and bending downwards. This rim was sometimes perfectly circular, but at others divided into a number of convex curves, forming so many distinct petals. The lotus, papyrus, and palm seem to have been the favourite plants for introduction into this kind of capital, and so beautifully were they carved, as frequently to exhibit the most delicate and minute parts, such as the petals, pistyles, reeds, &c. Examples are to be found in almost every building; among others we may mention those of Hermontis, Latopolis, and Apollinopolis Magna, where there are some exquisite specimens; indeed, all the capitals of this form are exceedingly delicate and beautiful, of elegant form, and chaste enrichment. An example of somewhat similar character is given selected from the temple of Esneh, but in this case the contour is different, being convex instead of concave; the treatment, however, is similar, and the design good. Another capital is frequently introduced in the greater temples, which may be termed a double capital, the lowermost of which consists of four Isis' faces, disposed so as to form a square larger than the shaft, the folds of the head-dress on each side hanging down, and projecting beyond it at the corners. Above each face is a projecting abacus, with a concave face, and standing upon these, a square temple, which forms the second capital. Instances are likewise to be found of triple capitals, which consist of the last-mentioned double form placed above one of the bell-shaped kind. Another instance of a double capital is given, taken from the temple of Typhon, which consists of a rectangular block placed upon a bell-shaped capital, against each of the four sides of which sits an image of the god. Heads of animals are sometimes carved in the place of capitals, amongst which are those of the bull, which form is worthy of notice as approximating to the capitals found at Persepolis. Rarely we find columns without capitals, or with a simple rectangular block, which is little better than an abacus. The Egyptian abacus varies from the Grecian in being nothing more than a plain square plinth, of considerably smaller dimensions than the capital, and therefore receding from, not projecting over, as in classical architecture; indeed it scarcely forms a member of the capital at all, for, on account of its great depth behind the capital, it is scarcely visible, unless it be of extraordinary height; its purpose seems to be, to form a marked division between the column and entablature, and obviate that heaviness of appearance which would otherwise be occasioned. The bulging capitals form an exception to this rule, for in them the abacus projects, and overhangs the capital, the object of which is apparent

from the peculiar shape of the capital; in this case it is usually ornamented with hieroglyphics or otherwise.

We have here referred to some few of the specimens of capitals which remain, and but a few, for there is a great variety, several of which may frequently be found in the same building: and even in the same hall, or other part of a building, may be seen capitals of different design though of the same general appearance, which circumstance is similar to that observable in Gothic buildings. The proportions vary in like manner; they seem to have had no settled rule as to design or proportion, which were purely matters of individual taste. The arrangement was generally picnostyle, especially in the covered halls, where they had to support large masses of stone, which were used for roofing.

The design for the entablature, on the contrary, seems to have been unalterable, for with the exception of some little diversity in the ornamentation, they are universally of the same form and character, and this is the case, however much buildings may differ as regards their columns. It comprises two parts only, the epistylium and the cornice, the former of which was flush with the walls underneath at each end of the colonnade, answering to the Greek antæ, with which likewise they are enclosed within a bold torus-moulding, and present a similar appearance to the architrave of a door being returned at the sides. The torus-moulding is a marked feature in Egyptian buildings, running up every angle of the building, and then returning on both sides underneath the cornice. The architrave is frequently plain, sometimes covered with hieroglyphics, but most frequently has a winged globe over the entrance in the centre, which is supposed to have been symbolical of the deity.

The cornice is a very prominent feature in this style, and is introduced as a crowning or finish in every situation, with or without the architrave: it is seen at the entrance of the temple, over the doorway and propylæa; within, over the colonnade and portico; and on the exterior, crowning the whole length of wall. It consists of but little more than a deep cove, but produces a great and beneficial effect by the bold shadow which it casts. The surface is divided into panels by an ornament similar to the Doric triglyph, or a band of three or more reeds placed side by side, with generally a narrow interval between each two; when, however, the band is composed of a greater number of reeds, they are placed close together. The metopes or panels are filled up with some kind of ornamentation. This formed the termination of the building, for the roof being flat, there was no such thing as the pediment, the finishing line was horizontal.

Let us return for a few moments to the column, the simplest form of which appears in an example at Beni-hassam, as figured by Mr. Barry, and in reference to which he says:

"The prototype would appear to have consisted of four large reeds of the Nile, placed upon an angular block, and tied together by cords near the top, forming thereby the capital. Small sticks are introduced between the reeds at the place of ligature, to render the figure of a more circular form, and afford the means of more firmly tying the whole together. The top is crowned by a square abacus, and the reeds being thereby confined, the effect of any incumbent weight upon them would be to produce the form."

A column similar to the above, but in a more forward state of development, is to be seen at the British Museum; it consists of double the number of reeds, placed together in the same manner, with similar base and abacus. But besides the difference as to number, there is in this example another variation in the method of joining shaft and base, the reeds in this case being turned under so as to meet the base in a curve, a form frequently adapted in more elaborate specimens.

The next change seems to have been the introduction of horizontal bands, which became requisite, as the reeds increased in number, to hold them firmly together; in some cases we find several bands, of one, two, or more reeds. The next step was to leave one or more of the spaces between the bands plain, and the next to cover it with hieroglyphics, till at last we find all the divisions of this description, at the Tentyris. The progress of the capital would seem to have been of a like nature; at first we find them composed of the same materials as the shaft, with only a band to mark the separation, and a flat square abacus at the top. The capital is, however, of a somewhat different contour, bulging out towards the lower end or ligature. In the second example we have adduced, the same form is preserved, but the capital and abacus, as well as the shaft, are covered with hieroglyphics. The next alteration would be similar to what took place in the case of the shaft: the capitals were divided horizontally into bands, as at Latopolis, and these again ornamented with hieroglyphics as at Kournou.

The bell-and-vase-shaped capitals are of an entirely different description, and cannot be said to have been a development of the above; they must have arisen from an entirely new adaptation of natural forms; while the above consists of mere reeds, the new form was an imitation of foliage and flowers belonging to that climate—the palm, the lotus, and the papyrus. The outline as well as the decoration of this kind of capital, deserves the highest praise for its taste, combining as it does the admirable properties of severity and grace, and will bear comparison with the best examples of classic design, not excepting the Corinthian, to which it bears a very remarkable resemblance, so much so as to give us reason to believe that the Romans were indebted to Egypt for the origin of their most admired order. Some specimens bear a slight resemblance to the Ionic; we may allude to that at Latopolis, but this is not so obvious, although we certainly have the upper part of the Ionic capital with its volutes repeated as a minor decoration.

The square capitals, again, with a representation of the head of Isis or other deity on its four sides, form a third class, which seems to have had its origin in symbolism, or at any rate in the mysteries of religion; a supposition which is in some measure confirmed by the usual accompaniment of a temple.

There are some columns to be seen in Egypt of a very different description to any we have noticed, and to which Mr. Barry has called attention in a note appended to Mr. Gwilt's edition of Chambers; they bear a marked resemblance to the Grecian Doric, and are considered of earlier date than any existing specimen of that order. One illustration represents a portico of two fluted columns in antis, the flutes of which are shallow, and twenty in number, and the capital consists of an abacus only; the height of the column is about 5½ diameters. Another striking example is found at Kalaptchie, on the borders of the Nile, in which, says Mr. Barry, "The abacus is square, and 11 inches thick; the shaft, which has a trifling diminution, is 7 feet 8 inches high, and 3 feet 2 inches diameter. The circumference is in 24 divisions, whereof 4, which are at right angles to each other, are flat faces covered with hieroglyphics, and the other intervening ones are sunk into flat elliptical flutes ¼-inch deep."

Another example is to be seen at Amada in Nubia, but here we have two different kinds adjoining each other, which throw some light upon the origin and purport of such columns. In this case the columns are but square piers with a slight projection at top and bottom, for abacus and base, not very different from those already described, as placed behind the Caryatid figures at Ipsambal; the pier at

the angle, however, presents a somewhat different appearance, for while the abacus and base remain as before, the shaft is both circular and fluted, the rounding of the angles seeming to have been effected as a matter of convenience, and the fluting as of ornament. We have already alluded to the not unfrequent occurrence of polygonal shafts, and we cannot help thinking that these, as well as the fluted examples just now described, find a common origin in the square pier of which they are all improvements. We are inclined to coincide with Mr. Barry in the following remarks :—" The general resemblance of the fluted columns to those of the Grecian Doric order, is manifest, and, in addition to many other remarkable indications in the Egyptian temple, clearly points to Egypt as the source of both Greek and Roman architecture." *See* Doric Order, Column.

Having now laid before the reader a general description of the elementary parts and details of Egyptian architecture, as well as of the usual form and distribution of their temples, it is our intention to give some more particular account of the more noted erections, and, in following out this scheme, we cannot do better than give the accounts of the various authorities in their own words.

The principal remains are to be found in Upper Egypt, in the cities lying on both sides of the Nile, but the spot in which they are most numerous and imposing, is in the neighbourhood of Thebes. The following is a list of the larger temples :—

Temple of Jupiter, at Karnac ; of Jupiter Ammon ; of Apollo, at Apollinopolis Magna ; of Osiris, at Tentyra ; of Venus ; of Thebais, at Knubis. Temples at Luxor, Dendera, Edfou, Esneh, or Latopolis, Hermopolis, Ombos, Syene, Queron, Ipsambul ; Caryatic temple, at Rhamesseion, and various temples in the islands of Philæ and Elephantina. In addition to which, we have the tombs and pyramids, the labyrinth, and various monuments, obelisks, and other isolated works.

We have already stated, that the grandest monuments are to be found at Thebes, and, of such, those of Karnac and Luxor take the pre-eminence ; they form two separate erections, but are connected together by a long avenue of sphinxes, as hereafter mentioned. We select these two as subjects for the first description, the authorities being Denon and Wilkinson.

For a general description of the temple at Karnac, we shall refer to the French traveller, M. Denon, who, writing at the latter end of the last century (1798-9), says :—

" It is the sumptuousness alone of the Egyptians which is to be seen at Karnac, where not only quarries, but mountains, are piled together, and hewn out into massive proportions, the traits of which are as feebly executed, as the parts are clumsily connected ; and these masses are loaded with uncouth bas-reliefs and tasteless hieroglyphics, by which the art of sculpture is disgraced. The only objects there which are sublime, both with regard to their dimensions and the skill which their workmanship displays, are the obelisks, and a few of the ornaments of the outer gates, the style of which is admirably chaste. If in the other parts of this edifice the Egyptians appear to us to be giants, in these latter productions they are geniuses. I am accordingly persuaded that these sublime embellishments were posteriorly added to the colossal monuments of Karnac. It must, however, be granted, that the plan of the temple is noble and grand. . . To the known descriptions of this great edifice of Karnac should be added, that it was but a temple, and could be nothing else. All that exists at present, in a somewhat entire state, relates to a very small sanctuary, and had been disposed in this way to inspire a due degree of veneration, and to become a kind of tabernacle. On beholding the vast extent of these ruins, the imagination is wearied with the idea of describing them. Of the 100 columns of the portico alone of this temple, the smallest are 7½ feet in diameter, and the largest 12. The space occupied by its circumvallation contains lakes and mountains. In short, to be enabled to form a competent idea of so much magnificence, it is necessary that the reader should fancy what is before him to be a dream, as he who views the objects themselves rubs his eyes to know whether he is awake. With respect to the present state of this edifice, it is, however, necessary, at the same time, to observe, that a great part of the effect is lost by its very degraded state. The sphinxes have been wantonly mutilated, with a few exceptions, which barbarism, wearied with destroying, has spared, and, on examining which, it is easy to distinguish, that some of them had a woman's head, others that of a lion, a ram, a bull, &c."

For the following more particular description of this temple, we are indebted to Sir I. G. Wilkinson.

" The principal entrance of the grand temple lies on the north-west side, or that facing the river. From a raised platform commences the avenue of Criosphinxes, leading to the front propyla, before which stood two granite statues of a Pharaoh. One of these towers retains a great part of its original height, but has lost its summit and cornice. In the upper part, their solid walls have been perforated through their whole breadth, for the purpose of fastening the timbers that secured the flag-staffs usually placed in front of these propyla ; but no sculptures have ever been added to either face, nor was the surface yet levelled to receive them. Passing through the pylon of these towers, you arrived at a large open court, 275 feet by 329, with a covered corridor on either side, and a double line of columns down the centre. Other propyla terminate this area with a small vestibule before the pylon, and form the front of the grand hall, 170 feet by 329, supported by a central avenue of 12 massive columns, 66 feet high (without the pedestal and abacus), and 12 in diameter ; besides 122 of smaller, or rather less gigantic dimensions, 41 feet 9 inches in height, and 27 feet 6 inches in circumference, distributed in seven lines on either side of the former. Other propyla close the inner extremity of this hall, beyond which are two obelisks, one still standing on its original site, the other having been thrown down and broken by human violence. A small propylon succeeds to this court, of which it forms the inner side ; the next contains two obelisks of larger dimensions, being 92 feet high and 8 square, surrounded by a peristyle, if I may be allowed the expression, of Osiride figures. Passing between two dilapidated propyla, you enter another smaller area, ornamented in a similar manner, and succeeded by a vestibule, in front of the granite gateway of the pyramidal towers, which form the façade of the court of the sanctuary. This last is also of red granite, divided into two apartments, and surrounded by numerous chambers of small dimensions, varying from 29 feet by 16, to 16 feet by 8. A few polygonal columns, of the early date of Osirtesen I., the contemporary of Joseph, appear behind these in the midst of fallen architraves of the same era, and two pedestals of red granite crossing the line of direction in the centre of the open space to the south-east, are the only objects worthy of notice, until you reach the column or edifice of the third Thothmes. The exterior wall of this building is entirely destroyed, except on the north-east side ; to it succeeds a circuit of thirty-two pillars, and within this square are twenty columns, disposed in two lines, parallel to the outer walls, and to the back and front row of pillars. Independent of the irregular position of the latter with regard to the columns of the centre, an unusual

caprice has changed the established order of the architectural details, and capitals and cornices are reversed, without adding to the beauty or increasing the strength of the building. A series of smaller halls and chambers terminates the extremity of the temple, one of which is remarkable as containing the names of the early predecessors of Thothmes III., their founder. In the western lateral adytum are the vestiges of a colossal hawk seated on a raised pedestal; the sculptures within and without containing the name of Alexander, by whose order this was repaired and sculptured.

"The total dimensions of this part of the temple behind the inner propyla of the grand hall, are 600 feet, by about half that in breadth, making the total length, from the front propyla to the extremity of the wall of circuit, inclusive, 1,180 feet. The additions made at different periods, by which the distant portions of this extensive mass of buildings were united, will be more readily understood from an examination of the survey itself than from any description, however detailed, I could offer to the reader; and from this it will appear that Diodorous is fully justified in the following statement: that 'the circuit of the most ancient of the four temples at Thebes measured thirteen stadia,' or about one mile and two-thirds English; the thickness of the walls, 'of 25 feet,' owing to the great variety in their dimensions, is too vague to be noticed; but the altitude of the building, to which he allows only 45 cubits, falls far short of the real height of the grand hall, which, from the pavement to the summit of the roof, inclusive, is not less than 80 feet."

The next description of Luxor is from the same writer:—

"Luqsor, which occupies part of the site of ancient Diospolis, still holds the rank of a market-town, the residence of a Kàshef, and head-quarters of a troop of Turkish cavalry. Its name signifies the Palaces, and some might perhaps feel inclined to trace in that of El Qasryn, or El Uqsorayn, (the dual of the word Qasr,) by which it is sometimes designated, the existence of the two distinct parts of this building, erected by Amunoph III. and Remeses II. The former monarch, who, at the time of its foundation, appears to have reigned conjointly with his brother, built the original sanctuary and circumjacent chambers, with the addition of the large colonnade and pylon before it, to which Remeses II. afterwards added the great court, the pyramidal towers, or propyla, and the obelisks and statues.

"These, though last in the order of antiquity, necessarily form the present commencement of the temple, which, like many others belonging to different epochs, is not 'two separate edifices,' but one and the same building. A dromos, connecting it with Karnak, extended in front of the two beautiful obelisks of red granite, whose four sides are covered with a profusion of hieroglyphics, no less admirable for the style of their execution, than for the depth to which they are engraved, which in many instances exceeds two inches.

"Two sitting statues of the same Remeses are placed behind these, one on either side of the pylon; but, like the obelisks, are much buried in the earth and sand accumulated around them. Near the north-west extremity of the propyla, another similar colossus rears its head amidst the houses of the village, which also conceal a great portion of the interesting battle-scenes on the front of these towers. At the doorway itself is the name of Sabaco, and on the abacus of the columns beyond, that of Ptolemy Philopater, both added at a later epoch.

"The area, whose dimensions are about 190 feet by 170, is surrounded by a peristyle, consisting of two rows of columns, now almost concealed by the hovels and mosk of the village. The line of direction no longer continues the same behind this court, the Remessean front having been turned to the eastward, in order to facilitate its connection with the great temple of Karnak, rather than to avoid the vicinity of the river, as might at first be supposed.

"Passing through the pylon of Amunoph you arrive at the great colonnade, where the names of this Pharaoh and his brother are sculptured. The latter, however, has been effaced, probably by order of the surviving monarch, as is generally the case wherever it is met with, and those of the immediate successor of Amunoph III. and of Osirei are introduced in its stead.

"The length of the colonnade to the next court is about 170 feet, but its original breadth is still uncertain, nor can it be ascertained without considerable excavation. To this succeeds an area of 155 feet by 167 surrounded by a peristyle of 12 columns in length and the same in breadth, terminating in a covered portico of 32 columns 57 feet by 111.

"Behind this is a space occupying the whole breadth of the building, divided into chambers of different dimensions, the centre one leading to a hall supported by 4 columns, immediately before the entrance to the isolated sanctuary.

"On the east of this hall is a chamber containing some curious sculpture, representing the accouchement of queen Maut-m-shoi, the mother of Amunoph and his brother; the two children nursed by the deity of the Nile, and presented to Amun, the presiding divinity of Thebes; and several other subjects relating to their education and subsequent history.

"The sanctuary, which had been destroyed by the Persians, was rebuilt by Alexander (the son of Alexander, Ptolemy being governor of Egypt,) and bears his name in the following dedicatory formula:

"'This additional work made he, the king of men, lord of the regions, Alexander, for his father Amunre, president of Tape (Thebes;) he erected to him the sanctuary, a grand mansion, with repairs of sand-stone, hewn, good, and hard stone, instead of his —— majesty, the king of men, Amunoph.' Behind the sanctuary are two other sets of apartments, the larger ones supported by columns, and ornamented with rich sculpture, much of which appears to have been gilded.

"Behind the temple is a stone quay, of the late era of the Ptolemies or Cæsars, since blocks bearing the sculpture of the former have been used in its construction. Opposite the corner of the temple, it takes a more easterly direction, and points out the original course of the river, which continued across the plain now lying between it and the ruins of Karnak, and which may be traced by the descent of the surface of that ground it gradually deserted. The southern extremity of this quay is of brick, and indicates in like manner the former direction of the stream, which now, having formed a recess behind it, threatens to sweep away the whole of its solid masonry, and to undermine the foundations of the temple itself.

The road to Karnak lies through fields of *halfeh* indicating the site of ancient ruins, and here and there, on approaching that magnificent building, the direction of the avenue, and the fragments of its sphinxes, are traced in the bed of a small canal, or watercourse, which the Nile, during the inundation, appropriates to its rising stream. To this succeeds another dromos of Criosphinxes, and a majestic pylon of Ptolemy Euergetes, with his queen and *sister* Berenice, who in one instance present an offering to their predecessors and parents, Philadelphus and Arsinöe. In one of the compartments within the doorway, the king is represented in a Greek costume, of which there are some other instances in Ptolemaic ruins. Another avenue of sphinxes extends to the propyla of the isolated temple behind this gateway, which was founded by Remeses IV., and continued by Remeses VIII.,

and a late Pharaoh, who added the hypæthral area and the propyla. His name, and the exact era at which he flourished, are not precisely ascertained; but if, as is very probable, we are authorized to read Bocchoris, this part will date in the time of the twenty-fourth dynasty, or about 810 B.C. Other names appear in different parts of the building, among which are those of Amyrteus and Alexander on the inner and outer gateways of the area."

Having made this digression in favour of Karnac and Luxor, we will now continue our descriptions, taking our examples in geographical order, commencing at the northern extremity of Upper Egypt, and travelling southwards. The first remains of which we have any notice are those of Hermopolis Magna, but they are little better than mounds of ruins, the portico described by Denon having been demolished. This portico was of great merit, and consisted of twelve columns in two rows of six each, surmounted with cornice and entablature. The next place we arrive at is Dendera, the ancient Tentyris, which contains ruins of several temples. The following account is given by Wilkinson.

"The name of Tentyris, or Tentyra, (in Coptic Tentoré, or Nikentore,) seems to have originated in that of the goddess Athor or Aphrodite, who was particularly worshipped there; and that the principal temple was dedicated to that goddess, we learn from the hieroglyphics, as well as from a Greek inscription of the time of Tiberius, in whose reign its magnificent portico was added to the original building. Egyptian sculpture had long been on the decline before the erection of this temple; and the Egyptian antiquary looks with little satisfaction on the graceless style of the figures, and the crowded profusion of ill-adjusted hieroglyphics, that cover the walls of Ptolemaic and Roman monuments; but architecture still retained the grandeur of an earlier period; and though the capitals of the columns were frequently overcharged with ornament, the general effect of the porticos erected under the Ptolemies and Cæsars, is grand and imposing, and frequently not destitute of elegance and taste. The same remarks apply to the temple of Dendera; and from its superior state of preservation, it deserves a distinguished rank among the most interesting monuments of Egypt. For though its columns, considered singly, may be said to have a heavy, and perhaps a grotesque, appearance, the portico is doubtless a noble specimen of architecture; nor is the succeeding hall devoid of beauty and symmetry of proportion. On the ceiling of the *pronaos*, or portico, is the Zodiac, which has led to much learned controversy, and which has at length, through the assistance of the Greek inscription, and the hieroglyphical names of the Cæsars that cover its exterior and interior walls, been confined to the more modest and probable antiquity of eighteen hundred years.

"The details of the cornice offer a very satisfactory specimen of the use of triglyphic ornament, which is common in many of the oldest Pharaohnic temples, though arranged in a somewhat different manner, and without so remarkable a metope as in the present instance.

"On the frieze, or rather architrave, is a procession to Athor, and among the figures that compose it are two playing the harp, and another with the tambourine. The inscription is on the projecting summit of the cornice, and commences with the name of the emperor Tiberius. Those of Aulus Avillius Flaccus, the military governor or prefect, and Aulus Fulmius Crispus, commander of the forces, though purposely erased, are still traced when the sun strikes obliquely on the surface of the stone; but the date of the emperor's reign is unfortunately lost.

"The small planisphere which was in one of the lateral chambers on the right-hand side of the temple, and behind the pronaos, has been removed to France, and from its position it probably dated a few years before the Zodiac. Numerous are the names of Cæsars in this temple. In the portico may be distinguished those of Tiberius, Caligula, Claudius, and Nero, and on the former front of the temple, now the back of the pronaos, are those of Augustus and Caligula. This was in fact the original extent of the building, and it was previous to the addition of the portico that it was seen by Strabo.

"The oldest names are of Ptolemy Cæsarion, or Neocæsar, and Cleopatra, who are represented on the back wall of the exterior; and it is probable that the whole *naos* was the work of the Ptolemies, though the sculptures remained unfinished till the reign of Tiberius, who, having erected the portico, added many of the hieroglyphics on the exterior walls.

"The portico is supported by twenty-four columns, and is open at the front, above the screens that unite its six columns; and in each of the side-walls is a small doorway.

"To this succeeds a hall of six columns, with three rooms on either side; then a central chamber, communicating on one side with two small rooms, and on the other with a staircase. This is followed by another similar chamber (with two rooms on the west, and one on the east side) immediately before the isolated sanctuary, which has a passage leading round it, and communicating with three rooms on either side. The total length of this temple is 93 paces (or about 220 feet,) by 41, or, across the portico, 50.

"In front of the temple was the dromos, extending for the distance of 110 paces to an isolated pylon, bearing the names of Domitian and Trajan. The attributes of Athor throughout this building very much resemble those of Isis; and she is in like manner represented nursing the young child Harpocrates, who is said, in the hieroglyphics, to be the 'son of Athor.'

"'Behind the temple of Venus,' says Strabo, 'is the chapel of Isis:' and this observation agrees remarkably well with the size and position of the small temple of that goddess; as it consists merely of one central and two lateral adyta, and a transverse chamber or corridor in front, and stands immediately behind the south-west angle of that of Athor. To it belonged the pylon that lies 170 paces to the eastward, and which, as we learn from a Greek inscription on either face of its cornice, was dedicated to Isis, in the thirty-first year of Cæsar (Augustus); Publius Octavius being military governor or prefect, and Marcus Claudius Posthumus, commander of the forces. In the hieroglyphics, besides the name of Augustus, are those of Claudius and Nero.

"Ninety paces to the north of the great temple of Athor is another building, consisting of two outer passage-chambers, with two small rooms on either side of the outermost one, and a central and two lateral adyta, the whole surrounded, except the front, by a peristyle of twenty-two columns. The capitals, ornamented or disfigured by the representation of a Typhonian monster, have led to the supposition that this temple was dedicated to the evil genius; but as the whole of its sculptures refer to the birth of Harpocrates, it is evident that it appertains to the great temple of Athor, who is here styled his mother; and it may be said rather to be dedicated to Harpocrates than to Typhon, who is only introduced in a subordinate character, as relating to the young deity. The names are of Trajan, Adrian, and Antoninus Pius.

"Around these buildings extends a spacious enclosure of crude brick, about 240 paces square, having two entrances, one at the pylon of Isis, the other at that before the great temple.

"About 230 paces in front of the pylon of Athor is an isolated hypæthral building consisting of fourteen columns, united by intercolumnar screens, with a doorway at either end; and a short distance to the south is the appearance of an ancient reservoir. A little to the north-east of it are other remains of masonry; but the rest of the extensive mounds of Tentyris present merely the ruins of crude brick houses, many of which are of Arab date.

"Five hundred paces east of the pylon of Isis is another crude brick enclosure, with an entrance of stone similar to the other pylons, bearing the name of Antoninus Pius. Over the face of the gateway is a singular representation of the sun, with its sacred emblem the hawk, supported by Isis and Nephthys. This enclosure is about 155 paces by 265, and at the south-east corner is a well of stagnant water.

"The town stood between this and the enclosure of the temples, and extended on either side, as well as within the circuit of the latter; but on the north-west side appear to be the vestiges of tombs.

"Between the town and the edge of the sandy plain to the south, is a low channel, which may once have been a canal; and it is not improbable that it was to this that the Tentyrites owed their insular situation mentioned by Pliny."

We next arrive at Kous, the site of the ancient Apollinopolis Parva, but the only distinguishable remains of the temple there consist of a large gate; proceeding therefore southward, we arrive at Thebes, the temples of which we have already described. On the opposite side of the river, however, we have several buildings worthy of note, of which the first is that of Qórneh or Kurnu, of which Wilkinson speaks thus:—

"To commence with the ruins nearest the river:—the first object worthy of notice is the small temple and palace at old Qórneh, dedicated to Amun, the Theban Jupiter, by Osirei, and completed by his son Remeses II., the supposed Sesostris of the Greeks. Its plan, though it evinces the usual symmetrophobia of Egyptian monuments, presents a marked deviation from the ordinary distribution of the parts which compose it. The entrance leads through a pyloné, or pylon, bearing, in addition to the name of the founder, that of Remeses III., beyond which is a dromos of 128 feet, whose mutilated sphinxes are scarcely traceable amidst the mounds and ruins of Arab hovels. A second pylon terminates this, and commences a second dromos of nearly similar length, extending to the colonnade or corridor in front of the temple, whose columns of one of the oldest Egyptian orders are crowned by an abacus, which appears to unite the stalks of waterplants that compose the shaft and capital.

"Of the intercolumniations of these ten columns, three only agree in breadth, and a similar discrepancy is observed in the doorways which form the three entrances to the building. The temple itself presents a central hall about fifty-seven feet in length, supported by six columns, having on either side three small chambers, one of which leads to a lateral hall, and the opposite one to a passage and open court on the east side. Upon the upper end of the hall open five other chambers, the centre one of which leads to a large room supported by four square pillars, beyond which was the sanctuary itself; but the dilapidated state of the north end of this temple affords but little to enable us to form an accurate restoration of the innermost chambers. The lateral hall on the west, which belonged to the palace of the king, is supported by two columns, and leads to three other rooms, behind which are the vestiges of other apartments; and on the east side, besides a large hypæthral court, were several similar chambers extending also to the northern extremity of its precincts."

The next building that attracts our notice is the Memnonium, and tomb of Osmandyas, of which ancient authors have given us such wonderful accounts; we give that of Diodorus Siculus:—

"Ten stadia from the tombs of the kings of Thebes," says this historian, "one admires that of Osimondué. The entrance to it is formed by a vestibule built with various-coloured stones. It is 200 feet long and 68 in elevation. On coming thence one enters under a square peristyle, each side of which is 400 feet long. Animals formed of blocks of granite 24 feet high, serve as columns to it, and support the ceiling, which is composed of squares of marble of 27 feet every way. Stars of gold, upon an azure ground, shine there the whole length of it. Beyond this peristyle opens another entry, followed by a vestibule built like the former, but more loaded with all sorts of sculpture. Before it are three statues formed of single stones, and hewn by Memnon Syenite. The principal one, which represents the king, is seated. It is the largest in Egypt; one of his feet, accurately measured, exceeds seven cubits. The two others, borne on his knees, one on the right, the other on the left, are those of his mother and his daughter. The whole work is less remarkable for its enormous size, than for the beauty of the execution and the choice of the granite, which in so extensive a surface has neither spot nor blemish. The colossus has this inscription:—'*I am Osimondué, the King of Kings; if any one wishes to know how great I am, and where I repose, let him destroy some of these works.*' Besides this, we see another statue of his mother, cut out of a single block of granite, and 30 feet high. Three queens are sculptured on the head, to show that she was daughter, wife, and mother, of a king.

"At the end of this portico, one enters into a peristyle more beautiful than the former. On a stone is engraved the history of the war of Osimondué against the revolted inhabitants of Bactria. The façade of the front wall shows this prince attacking ramparts, at the foot of which runs a river. He combats advanced troops, having by his side a terrible lion, which defends him with ardour. The wall on the right presents captives in chains, their hands and private parts cut off, in order to stigmatize their cowardice. On the wall to the left, different symbolical figures, very well sculptured, recall the triumphs and the sacrifices of Osimondué on his return from this war. In the middle of the peristyle, at the place where it is exposed, an altar was prepared, composed of a single stone of marvellous size, and of exquisite workmanship. In short, against the bottom wall, two colossuses, each of them of one block of marble, and 40 feet high, are seated on their pedestals. One comes out of this admirable peristyle by three gates; one of them between two statues, the two others are on the sides; they lead to an edifice 200 feet long, the roof of which is supported by 8 columns. It resembles a magnificent theatre; several figures in wood represent a senate employed in distributing justice. On one of the walls one observes 30 senators, and in the midst of them the president of justice, having at his feet a collection of books, and the figure of Truth with her eyes shut, suspended at his neck. One passed thence into a square surrounded by palaces of different forms, where were seen carved on the table all sorts of dishes which could flatter the taste. In one of them, Osimondué, clad in a magnificent dress, was offering to the gods the gold and silver he drew yearly from the mines of Egypt. Below was written the value of this revenue, which amounted to 32 millions of silver minas. Another palace contained the sacred library, at the entrance of which, one read these words: *Remedies for the Soul.* A third contained all the divinities of Egypt,

with the king, who offered to each of them the suitable presents; calling Osiris, and the princes his predecessors, to witness that he had exercised piety towards the gods and justice towards men. By the side of the library, in one of the most beautiful buildings of the place, were to be seen twenty tables surrounded by their beds, on which reposed the statues of Jupiter, Juno, and Osimondué. His body is thought to be deposited in this place. Several adjoining buildings preserved the representations of all the sacred animals of Egypt. From these apartments one mounted to the king's tomb, on the top of which was placed a crown of gold, a cubit wide, and 365 round. Each cubit answered to one day of the year, and the rising and setting of the stars for that day was engraven on each of them, with such astrological observations as the superstition of the Egyptians attached to them. It is said that Cambyses carried off this circle when he ravaged Egypt. Such, according to historians, was the tomb of Osimondué, which surpassed all others, both by its extent, and by the labour of the able artists employed on it."

Upon this passage Savary remarks, "I dare not take upon me to warrant all these facts, advanced by Diodorus Siculus on the authority of preceding writers; for in his time the principal part of these buildings no longer existed. I admit even that all these wonderful decsriptions would pass for pure chimeras in any other country; but in this fruitful land, which seems to have been first honoured with the creative genius of the arts, they acquire a degree of probability. Let us examine what remains to us of these monuments, and our eyes will compel us to believe in prodigy. Their ruins are in heaps, near to *Medinet Abou*, in the space of half a league's circumference. The temple, the peristyles, the vestibules, present to the eye nothing but piles of ruins, amongst which rise up some pyramidal gates, whose solidity has preserved them from destruction; but the numerous colossuses described by Diodorus, are still subsisting, though mutilated. That which is nearest to these ruins, composed of yellow marble, is buried two-thirds of its height in the earth. There is another in the same line, of black and white marble, the back of which is covered with hieroglyphics for 30 feet in length. In the space betwen them, trunks of columns and broken statues cover the ground, and mark the continuation of the vestibules. Farther on we distinguish two other colossal statues, totally disfigured. A hundred toises from them, the traveller is struck with astonishment at the sight of two colossuses, which, like rocks, are seated by the side of each other. Their pedestals are nearly equal, and formed of blocks of granite 30 feet long, and 18 feet wide. The smallest of these colossuses is also of a single block of marble; the other, which is the largest in Egypt, is formed of five courses of granite, and broken in the middle; it appears to have been the statue of Osimondué, for one sees two figures cut in *relievo*, the length of his legs, and which are about one-third of his height. These are the mother and the daughter of this prince. The other colossus, which is of one stone, and which corresponds with the dimensions of Diodorus Siculus, represented also the mother of the king. To give you an idea of the gigantic stature of the great colossus, it is enough to tell you, that his foot alone is near 11 feet long, which answers exactly to the seven cubits of Diodorus. This statue, the half of which remains upon its base, and is what Strabo calls the statue of Memnon, uttered a sound at the rising of the sun. It possessed formerly great renown. Several writers have spoken of it with enthusiasm, regarding it as one of the seven wonders of the world. A multitude of Greek and Latin inscriptions, that are still legible, on the base and the legs of the colossus, testify that princes, generals, governors, and men of every condition, have heard this miraculous sound."

The following account of a portion of the above, which is given somewhat more in detail, is from Wilkinson.

"Following the edge of the cultivated land, and about 180 yards to the west of this building, are two mutilated statues of Remeses II., of black granite, with a few substructions to the north of them; and 770 yards farther to the west, lies, in the cultivated soil, a sandstone block of Remeses III., presenting in high relief the figure of that king, between Osiris and Pthah; 1,400 feet beyond this, in the same direction, is a crude brick enclosure, with large towers, which once contained within it a sandstone temple, dating probably from the reign of the third Thothmes, whose name is stamped on the bricks, and who appears to have been the contemporary of Moses.

"Other fragments and remains of crude brick walls proclaim the existence of other ruins in its vicinity; and about 1,000 feet farther to the south-west, is the palace and temple of Remeses II., erroneously called the Memnonium: a building which, for symmetry of architecture and elegance of sculpture, can vie with any other monument of Egyptian art. No traces are visible of the dromos, that probably existed before the pyramidal towers which form the façade of the first hypæthral area, a court whose breadth of 180 feet, exceeding the length by nearly 13 yards, is reduced to a more just proportion, by the introduction of a double avenue of columns on either side, extending from the towers to the north wall. In this area, on the right of a flight of steps leading to the next court, was the stupendous Syenite statue of the king seated on a throne, in the usual attitude of these Egyptian figures, the hands resting on his knees, indicative of that tranquillity which he had returned to enjoy in Egypt, after the fatigues of victory. But the fury of an invader has levelled this monument of Egyptian grandeur, whose colossal fragments lie scattered around the pedestal, and its shivered throne evinces the force used for its demolition.

"If it is a matter of surprise how the Egyptians could transport and erect a mass of such dimensions, the means employed for its ruin are scarcely less wonderful; nor should we hesitate to account for the shattered appearance of the lower part by attributing it to the explosive force of powder, had that composition been know at the period of its destruction. The throne and legs are completely destroyed, and reduced to comparatively small fragments, while the upper part, broken at the waist, is merely thrown back upon the ground, and lies in that position which was the consequence of its fall; nor are there any marks of the wedge, or other instrument, which should have been employed for reducing those fragments to the state in which they now appear. The fissures seen across the head, and in the pedestal, are the work of a later period, when some of these blocks were cut for millstones by the Arabs, but its previous overthrow will probably be coeval with the Persian invasion. To say that this is the largest statue in Egypt, will convey no idea of the gigantic size or enormous weight of a mass, which, from an approximate calculation, exceeded, when entire, nearly three times the solid content of the great obelisk of Karnak, and weighed about 887 tons, 5 hundredweight and a half.

"No building in Thebes corresponds with the description given of the tomb of Osymandyas by Hecatæus. Diodorus, who quotes his work, gives the dimensions of the first or outer court, two plethra, or 181 feet 8 inches English, agreeing very nearly with the breadth, but not the length of that now before us; but the succeeding court, of four

plethra, neither agrees with this, nor can agree with that of any other Egyptian edifice; since the plan of an Egyptian building invariably requires a diminution, by no increase of dimensions, from the entrance to the inner chambers; and while the body of the temple, behind the portico, retained one uniform breadth, the areas in front, and frequently the portico itself, exceeded the inner portion of it by their projecting sides. The peristyle and 'columns in the form of living beings,' roofed colonnade, sitting statues, and triple entrance to a chamber supported by columns, agree well with the approach to the great hall of this temple. The largest statue in Egypt can scarcely be looked for but in the building before us, yet the sculptures to which he alludes, remind us rather of those of Medeenet Hábоо; nor is it impossible that either Hecatæus or Diodorus have united or confounded the details of these two edifices.

"The second area is about 140 feet by 170, having on the south and north sides a row of Osiride pillars, connected with each other by two lateral corridors of circular columns. Three flights of steps lead to the northern corridor behind the Osiride pillars, the centre one having on each side a black granite statue of Remeses II., the base of whose throne is cut to fit the talus of the ascent. Behind these columns, and on either side of the central door, is a limestone pedestal, which, to judge from the space left in the sculptures, must have once supported the sitting figure of a lion, or perhaps a statue of the king. Three entrances thence open into the grand hall, each strengthened and beautified by a sculptured doorway of black granite, and between the two first columns of the central avenue, two pedestals supported (one on either side) two other statues of the king. Twelve massive columns form a double line along the centre of this hall, and eighteen of smaller dimensions, to the right and left, complete the total of the forty-eight which supported its solid roof, studded with stars on an azure ground. To the hall, which measures 100 feet by 133, succeeded three central and six lateral chambers, indicating, by a small flight of steps, the gradual ascent of the rock on which this edifice is constructed. Of nine, two only of the central apartments now remain, each supported by four columns, and each measured about 30 feet by 55; but the vestiges of their walls, and appearance of the rock, which has been levelled to form an area around the exterior of the building, point out their original extent. The sculptures, much more interesting than the architectural details, have suffered still more from the hand of the destroyer; and of the many curious battle-scenes which adorned its walls, four only now remain."

Still southward is the village of Medeenet Haboo, which contains the ruins of two temples, of which we have not space to give a particular account. The smaller one consists of an open area 125 feet by 80, the north side being formed of a row of eight columns, through which access is obtained to a transverse area, having two pyramidal towers at its extremity, and between them an entrance into an hypæthral court with similar towers. These lead into a court 60 feet long, with a colonnade on either side, and at its extremity an entrance into the sanctuary, which is surrounded by colonnades and chambers. The larger edifice is approached through a dromos 265 feet in length, at the end of which are two propylæa leading into a large hypæthral court. At the further side of this court an entrance through pylons is given into a very fine peristyle court 123 feet by 133 feet, at the extremity of which is the portico. The large court contains specimens of Caryatid columns.

We now arrive at a different class of buildings—the tombs or catacombs, which consist of subterranean apartments and passages excavated out of the rock, and extending over a vast tract of land in the neighbourhood of Thebes, near Kurnu. The two following descriptions are from the writer previously quoted; the first relates to one of the tombs of the kings, which was first opened by Belzoni:—

"The tomb, which of all others stands pre-eminently conspicuous, as well for the beauty of its sculpture as the state of its preservation, is undoubtedly that discovered and opened by Belzoni. But the plan is far from being well regulated, and the deviation from one line of direction greatly injures its general effect; nor does the rapid descent by a staircase of twenty-four feet in perpendicular depth, on a horizontal length of twenty-nine, convey so appropriate an idea of the entrance to the abode of death, as the gradual talus of other of these sepulchres. To this staircase succeeds a passage of eighteen feet and a half by nine, including the imposts; and, passing another door, a second staircase descends in horizontal length twenty-five feet; beyond which two doorways, and a passage of twenty-nine feet, bring you to an oblong chamber twelve feet by fourteen, where a pit, filled up by Belzoni, once appeared to form the utmost limit of the tomb. Part of its inner wall was composed of blocks of hewn stone, closely cemented together, and covered with a smooth coat of stucco, like the other walls of this excavated catacomb, on which was painted a continuation of those subjects that still adorn its remaining sides.

"Independent of the main object of this well, so admirably calculated to mislead, or at last check, the search of the curious and the spoiler, another advantage was thereby gained in the preservation of the interior part of the tomb, which was effectually guaranteed from the destructive inroad of the rain-water, whose torrent its depth completely intercepted; a fact which a storm, some years ago, by the havoc caused in the inner cambers, sadly demonstrated.

"The hollow sound of the wall above-mentioned, and a small aperture, betrayed the secret of its hidden chambers, and a palm-tree, supplying the place of the more classic ram, forced, on the well-known principle of that engine, the intermediate barrier, whose breach displayed the splendour of the succeeding hall, at once astonishing and delighting its discoverer, whose labours were so gratefully repaid.

"Its four pillars, supporting a roof twenty-six feet square, are decorated, like the whole of the walls, with highly-finished and well-preserved sculptures, which, from their vivid colours, appear but the work of yesterday; and near the centre of the inner wall, a few steps lead to a second hall of similar dimensions, supported by two pillars, but left in an unfinished state, the sculptors not having yet commenced the outline of the figures the draughtsmen had but just completed. It is here that the first deviations from the general line of direction occur, which are still more remarkable in the staircase that descends at its southern corner.

"To this last succeed two passages, and a chamber seventeen feet by fourteen, communicating by a door, *nearly* in the centre of its inner wall, with the grand hall, which is twenty-seven feet square, and supported by six pillars. On either side is a small chamber opposite the angle of the first pillars, and the upper end terminates in a vaulted saloon, nineteen feet by thirty, in whose centre stood an alabaster sarcophagus, the kenotaph of the deceased monarch, upon the immediate summit of an inclined plane, which, with a staircase on either side, descends into the heart of the argillaceous rock for a distance of a hundred and fifty feet. This, like the entrance of the tomb and the first hall, was closed and concealed by a wall of masonry, which, coming even with the base of the sarcophagus, completely masked the staircase it covered and levelled with the floor.

"A small chamber and two niches are perforated in the north-west wall; at the upper end a step leads to an unfinished chamber, 17 feet by 43, supported by a row of four pillars; and on the south-west are other niches and a room about 25 feet square, ornamented with two pillars and a broad bench (hewn, like the rest of the tomb, in the rock) around three of its sides, four feet high, with four shallow recesses on each face, and surmounted by an elegant Egyptian cornice. It is difficult to account for the purport of it, unless its level summit served as a repository for the mummies of the inferior persons of the king's household; but it is more probable that these were also deposited in pits.

"The total horizontal length of this catacomb is 320 feet, without the inclined descent below the sarcophagus, and its perpendicular depth 90, or, including that part, about 180 feet, to the spot where it is closed by the fallen rock."

The second description is of tombs of more recent date, executed during the twenty-sixth dynasty, in the seventh century before our era; they are of great extent, and unusual uniformity.

"The smallest, which are those behind the palace of Remeses, commence with an outer court decorated by a peristyle of pillars, and to this succeeds an arched entrance to the tomb itself, which consists of a long hall, supported by a double row of four pillars, and another of smaller dimensions beyond it, with four pillars in the centre. The largest of them, and indeed of *all* the sepulchres of Thebes, are those in the Assaseef, one of which far exceeds in extent any one of the tombs of the kings. Its outer court, or area, is 103 feet by 76, with a flight of steps descending to its centre from the entrance, which lies between two massive crude brick walls, once supporting an arched gateway. The inner door, cut like the rest of the tomb in the limestone rock, leads to a second court, 53 feet by 67, with a peristyle of pillars on either side, behind which are two closed corridors; that on the west containing a pit and one small square room, the opposite one having a similar chamber, which leads to a narrow passage, once closed in two places by masonry, and evidently used for a sepulchral purpose.

"Continuing through the second area you arrive at a porch, whose arched summit, hollowed out of the rock, has the light form of a small segment of a circle, and from the surface of the inner wall are relieved the cornice and mouldings of an elegant doorway.

"This opens on the first hall, 53 feet by 37, once supported by a double line of four pillars, dividing the nave (if I may so call it) from the aisles, with half-pillars, as usual, attached to the end-walls. Another ornamented doorway leads to the second hall, 32 feet square, with two pillars in each row, disposed as in the former. Passing through another door, you arrive at a small chamber, 21 feet by 12, at whose end-wall is a niche, formed of a series of jambs, receding successively to its centre. Here terminates the first line of direction. A square room lies on the left (entering), and on the right another succession of passages, or narrow apartments, leads to two flights of steps, immediately *before* which is another *door* on the right. *Beyond* these is another passage, and a room containing a pit 45 feet deep, which opens at about one-third of its depth on a lateral chamber.

"A third line of direction, at right angles with the former, turns to the right, and terminates in a room, at whose upper end is a squared pedestal.

"Returning through this range of passages, and re-ascending the two staircases, the *door* above alluded to presents itself on the left hand. You shortly arrive at a pit (opening on another set of rooms, beneath the level of the upper ground-plan), and after passing it, a large square, surrounded by long passages, arrests the attention of the curious visitor. At each angle is the figure of one of the eight following goddesses:—Neith, Sate, Isis, Nephthys, Netpe, Justice, Selk, and Athor, who, standing with outspread arms, preside over and protect the sacred inclosure, to which they front, and are attached.

"A gentleman, an author, whose reading is far more respectable than his judgment, has not failed to discover something extraordinary in the position of these figures, referring, as he supposes, to the crucifix, adopted by the Christians.

"Eleven niches, in six of which are small figures of different deities, occur at intervals on the side-walls, and the summit is crowned by a frieze of hieroglyphics. Three chambers lie behind this square, and the passage which goes round it *descends* on that side, and rejoins, by an *ascending* talus on the next, the level of the front. A short distance further terminates this part of the tomb, but the above-mentioned pit communicates with a subterranean passage opening on a vaulted chamber, from whose upper extremity another pit leads, *downwards*, to a second, and ultimately through the ceiling of the last, *upwards*, to a third apartment, coming immediately below the centre of the square above noticed. This has one central niche, and seven on either side, the whole loaded with hieroglyphical sculptures, which cover the walls in every part of this extensive tomb.

"But to give an idea of its length, and, consequently, of the profusion of its ornamental details, I shall briefly state the total extent of each series of the passages both in the upper and under part of the excavation. From the entrance of the outer area to the first deviation from the original right line, is 320 feet. The total of the next range of passages to the chamber of the great pit, is 177 feet. The third passage, at right angles to this last, is 60 feet; that passing over the second pit, is 125; and adding to these three of the sides of the isolated square, the total is 862 feet, independent of the lateral chambers.

"The area of the actual excavation is 22,217 square feet, and with the chambers of the pits 23,809, though, from the nature of its plan, the ground it occupies is nearly one acre and a quarter, an immoderate space for the sepulchre of one individual, even allowing that the members of his family shared a portion of its extent."

At Hermontis, a short distance south of Thebes, are the ruins of a small temple, consisting of a colonnaded court with portico and sanctuary, and some distance beyond this, more extensive remains at Esneh, or Latopolis, but the only portion uncovered is a portico of considerable pretensions. Passing by several monuments more or less remarkable, we arrive at Edfou, or Apollinopolis Magna, the temple of which has already been described; and beyond this, at Ombos, where are ruins of two temples, one of which is remarkable for having a double entrance, and two sanctuaries side by side. In our way to the islands of Philöe and Elephantina, we would stop for a moment at Syene to notice the quarries of granite from which a great portion of the stone for building was supplied, previous to the working of the quarries near Philöe. The islands of Philöe and Elephantina are rich in remains, but more especially the former, which we accordingly select for illustration. Denon says:—

"As soon as I could set foot in the island (Philöe) I began first by going over all the inner part, to take a general survey of the various monuments, and to form a kind of topographical chart, containing the island, the course of the river, and the adjacent characteristic scenery. I found a convincing proof that this group of monuments had been constructed at different

periods, by several nations, and had belonged to different forms of religious worship; and the union of these various edifices, each of them in itself regular, and crowded together in this narrow spot, formed an irregular group of most picturesque and magnificent objects. I could here distinguish eight sanctuaries or separate temples, of different dimensions, built at various times, and the limits of each had been respected in the construction of the succeeding ones, which had impaired the regularity of the whole. A part of the additions to the original buildings had been made with a view of connecting the old to the new, avoiding, with great dexterity, false angles and general irregularities. This kind of confusion of the architectural lines, which appear like errors in the plan, produce in the elevation a picturesque effect, which geometrical rectitude cannot give; it multiplies objects, forms elegant groups, and offers to the eye more richness than cold symmetry can ever command. I was here able to convince myself of the truth of a remark which I had before made at Thebes and Tentyra, which is, that the mode of building with the ancient Egyptians was, first, to erect large masses, on which they afterwards bestowed the labour of ages in the particulars of the decoration, beginning their work with shaping the architectural lines, proceeding next to the sculpture of the hieroglyphics, and concluding with the stucco and the painting. All these distinct periods of work are very obvious here, where nothing is finished but what belongs to the highest antiquity; where, as a part of the subordinate buildings which served to connect the various monuments, had been left in many particulars without finish, without sculpture, and even incomplete in the building. The great and magnificent oblong monument exhibits these different periods of workmanship; it would be difficult to assign any use to this edifice, if the presence of certain monuments representing offerings, had not pointed it out to be a temple. It has, however, the form neither of a portico, nor of a temple; the columns which compose its outer circumference, and which are engaged in the wall only half their height, support nothing but an entablature, and a cornice without roof or platform; it only opened by two opposite doors, without lintels, which made a straight passage through, in a longitudinal direction. As it was doubtless built in the later period of the Egyptian power, it shows the perfection of art in the highest purity; the capitals are admirable in beauty and execution; the volutes and the foliage are gracefully waved, like the finest Greek architecture, and are symmetrically diversified like those of Apollinopolis, that is to say, differing from the contiguous capitals, and similar to the corresponding ones, and all are exactly kept within the same parallel."

This group of buildings is 800 feet long and 420 feet broad, and it is almost entirely covered with the most stately monuments of different ages. The front is a rampart wall, to serve as a protection against the rising waters of the Nile. The entrance to the temple was approached by a magnificent double range of columns around a court 250 feet long, behind which were rooms for the priests. The pyramidal môles are each 47 feet long, 27 feet thick, and 75 feet high; two rows of gigantic hieroglyphics adorn them, representing five of their grand divinities; there are likewise other figures of priests, &c.; on each side of the door (which is 26 feet high) is an obelisk 18 feet high, and a sphinx 7 feet long. Behind is a court 80 feet long, and 45 feet wide, also flanked by galleries of columns. On the right, behind the columns, is a suite of cells 10 feet deep, and on the left a private dwelling, composed of a portico at each end, and of three rooms of various dimensions, communicating one with another, and opening to the porticos; this is the only building that Denon ever saw of the kind. Two other môles serve as the portal to the most beautiful and regular part of the edifice; this is a species of portico, decorated by 10 columns and 8 pilasters 4 feet in diameter, as magnificent as they are elegant; the columns and walls are covered with sculptures, the ceilings are either painted in astronomical tables, or with white stars on an azure ground. Beyond this again was the secret part of the temple, 60 feet by 30, divided into four rooms, one leading to the others; in these remote chambers it is supposed that the sacred birds and reptiles were kept.

"Besides this vast enclosure, in which these numerous temples were connected and grouped together by dwellings for the priests, there were two temples standing apart; the larger of the two I have already spoken of, the smaller is one of the most beautiful that can be conceived, in perfect preservation, and so small, that it almost gives one the desire of carrying it away. I found within it some remains of a domestic scene, which seemed to be that of Joseph and Mary, and suggested to me the subject of the flight into Egypt in a style of the utmost truth and interest."

We have now described several of the principal monuments belonging to this style of architecture, from which may be formed a very fair idea of the Egyptian method of arranging and adorning their temples. We have not touched upon the pyramids, although the subject can scarcely be said to be completed without some description of them; we have, however, already extended this article to a somewhat inconvenient length, and would rather defer their consideration to a later period, than treat them here in a summary and insufficient manner. The same reasoning applies to the description of the sphinxes, and such like. We refer the reader, therefore, to the articles under the heads PYRAMID and SPHINX.

The subject we have been treating of is one of very considerable interest, and, although not of direct practical utility to the architect, is yet well worthy his careful consideration.

EGYPTIAN-HALL, OR BANQUETING-ROOMS. *See* ŒCUS.

EGYPTIAN PYRAMIDS. *See* PYRAMIDS.

EIDOGRAPH, an instrument for copying designs, invented by Professor Wallace, of Edinburgh. The eidograph is an improvement on the pentagraph in common use, is much more correct, and can be used for purposes to which the latter cannot be applied.

EIDOLON, a likeness, image, or representation.

ELBOWS OF A WINDOW, the two flanks of panelled work, one under each shutter, generally tongued or rebated into the back, so that the two elbows and the back form a lining round the three sides of the recess.

ELEOTHESION, the anointing-room, belonging to the palestræ, called by the Romans *unctuarium*. *See* PALESTRÆ.

ELEVATION, an orthographical projection, made on a plane perpendicular to the horizon. In architecture, as buildings are constructed with vertical faces or fronts, the plane of delineation is generally chosen parallel to a side, in order that the measure in every direction may be readily obtained. What is generally called a section, partakes as much of a geometrical projection or elevation, as a section. By the elevations and plans, all the measures of an original object may be ascertained, whether the lines or arrises represented be horizontal, vertical, or inclined. In orthographical projections, all straight lines perpendicular to the plane of delineation are projected into points, and all straight lines parallel to the plane of delineation, are projected into straight lines of equal lengths, and are alike situated with regard to the plane of delineation, as the straight arris in the original object is with regard to the naked face of the wall. Therefore, whatever lines are perpendicular to the elevation,

they will be represented by points, and whatever arrises are parallel to the elevation, they will be represented by lines parallel to the original. *See* DESIGN.

ELIZABETHAN ARCHITECTURE. *See* TUDOR ARCHITECTURE.

ELLIPSIS, or ELLIPSE, in geometry, a conic section formed by cutting a cone entirely through the curved surface, neither parallel to the base, nor making a subcontrary section; so that the ellipsis, like the circle, is a curve that returns into itself, and completely encloses a space. See the definitions under the word CONE.

One of the principal and most useful properties of the ellipsis is, that the rectangle under the two segments of a diameter is as the square of the ordinate. In the circle, the same ratio obtains, but the rectangle under the two segments of the diameter becomes equal to the square of the ordinate:

Problem 1.—*The two axes of an ellipsis being given to describe the curve.*

Method I.—*Figure* 1. Let A C be the greater axis, BG the lesser, cutting each other in the centre H; and if with the radius A H, or H C, from the point B, an arc E F be described, it will cut A C, at E and F, the foci; fix two pins at E and F; take a thread equal in length to A C, and fix one end of it to E, and the other to F; then keeping a pencil at the point D, move such point forward in the same direction, so that the parts D E and E F may continue to be stretched during the motion, until the describent D come to the point whence it began to move.

Method II.—*Figure* 2. Find the foci E and F, as before; between E and F, take any point, 1; with the radii A 1, 1 C, and the centres E and F, describe arcs cutting each other at G, as also at H; then G and H are points in the curve; in the same manner, with the same radii, from the centres F and E, find the intersections I and K. In like manner, if any other point, 2, be taken between E and F; four other points, L, M, N, O, will be obtained, and thus as many more as will be requisite for drawing the curve by hand.

For by the construction of the ellipsis, $ED + DF$, (*Figure* 1) is equal to $EC + CF, = EF + 2FC$; also $ED + DF = FA + AE = EF + 2AE$; therefore $EF + 2FC = EF + 2AE$: consequently AE is equal to FC; hence $ED + DF = EF + 2AE = EF + 2FC$: that is, the sum of the two lines drawn from the foci, to any point in the curve, is equal to the transverse axis.

Method III.—*Figure* 3. *To describe an ellipsis with the ellipsograph, or trammel, as it is called by workmen, the axes* A B *and* C D *being given in position, bisecting each other in the centre* E.—In any piece of material, contained between any two parallel planes, cut two grooves, at right angles to each other, in one of the planes; then provide a rod with three pins, or points, so that at least two may be moveable, and in a straight line with the third: let H F G be the rod, with the points F and G moveable; making H G equal to the greater semi-axis; then placing the grooves over the axes, and putting the points F and G in the two grooves, move the point H round, keeping the point F upon the greater axis, A B, and the point G upon the lesser axis C D, until the describent H come to the point where the motion commenced; and the figure so described, will be an ellipsis. The trammel, used by artificers, consists of two rulers, with a groove in each, so fixed that both grooves may be in the same plane, and at right angles to each other, and that the opposite sides of the cross may be in a plane parallel to those of the grooves. The rod above, is a bar with two moveable cursors, the fixed end is made to hold a pencil, and each of the other two an iron point, made to fill the groove, but capable of sliding freely.

Method IV.—*Figure* 4. *Given one of the axis,* A B, *and an ordinate,* C D, *to describe the ellipsis.*—Bisect A B at I for the centre; through I draw E F, parallel to C D; with the distance I A, or I B, from the point D, describe an arc, cutting I F at G; draw the straight line D G H, cutting I A at H; then if H D G be conceived to be an inflexible line or rod, the points H, G, D, remaining at the same distance in respect to each other; and if the point H be moved in the axis A B, and the point G in the axis E F, while the describent D, is carried round the centre, I, until A come to the point whence it began to move; a curve D B E A F, will be described, which will be an ellipsis.

Demonstration.—Figure 5.

$$LF, \text{ or } BK : FG, \text{ or } DB :: LC, \text{ or } AB \,.\, CD,$$

Therefore, $BK^2 : DB^2 :: AB^2 : CD^2$;

$BK^2 : BK^2 - DB^2 :: AB^2 : AB^2 - CD^2$.

But $BK^2 - DB^2 = BK + BD \times BK - BD = DH \times DK$

and $CD^2 = CL^2 - DL^2 = AB^2 - LD^2$.

Consequently, $BK^2 : DH \times DK :: AB^2 : DL$ which is a most principal property of the ellipsis, but the demonstration which accompanies the following method, is quite general, for every two diameters.

Method V.—*Figure* 6. *A diameter,* K H, *and an ordinate,* D L, *of an ellipsis being given, to describe the curve by a continued motion.*—Bisect K H at I, and through I, draw A I A, parallel to D L; draw D E C, and K B, at right angles to A A; from L, with the distance K B, describe an arc, cutting I A at F; draw I F C; through the points C and I, draw M N; then if the point C be moved in M N, and the point F in A A, the point L will describe the curve of an ellipsis.

Demonstration.

For the triangles L F G, and L C D are similar ∴ $LF : FG :: LC : CD$;

But because $FL = BK$, $FG = DE$, and $LC = AI$, $KB : DE :: AI : CD$;

Again, by similar triangles, I K B, and I D E . . $KB : DE :: KI : DI$;

Therefore, by equality of ratios . . . . $KI : DI :: AI : CD$;

By duplication . . . . $KI^2 : DI^2 :: AI^2 : CD^2$;

By division . . . . $KI^2 : KI^2 - DI^2 :: AI^2 : AI^2 - CD^2$.

But $KI^2 - DI^2 = (KI + DI) \times (KI - DI) = DH \times DK$;

and $CD^2 = LC^2 - LD^2 = AI^2 - LD^2$.

Therefore by substituting $DH \times DK$, for $KI^2 - DI^2$, and $AI^2 - LD^2$, for CD^2;

In the last analogy we have . . . . $KI^2 : DH \times DK :: AI^2 : LD^2$,

a well-known property of the ellipsis.

The method for describing an ellipsis, having two conjugate diameters given, may be found in the Marquis de l'Hospital's *Treatise of Conic Sections*, translated by Stone. But the author of the *Architectural Dictionary* has chosen to give the description and demonstration from a diameter and double ordinate instead of two conjugate diameters, as being more readily applied in perspective. It is strange, that this useful method has been neglected by all English writers that have fallen in our way. This property was discovered by the author, and demonstrated by him, many years before he met with the above work, in endeavouring to find out methods for describing the perspective representation by continued motion.

Method VI.—*Figure* 7. No. 1. Let A B be the greater axis, bisected in C, by the lesser semi-axis C D; take two rulers, C E and E F, of equal length, equal to the sum of the semi-axes C D and C B, moveable upon each other at E, and the end C of the rule C E, moveable upon the centre of the ellipsis. Make the part F G of the ruler, F E, equal to the semi-axis C D; now suppose C E and E F to coincide with each other, and with the axis C D; then move the point F from C, in the direction C B, until the describent G arrive at B: the point G will then have traced the quadrant D B of the ellipsis. The other quadrants will be described in the same manner, by reversing and inverting the rulers.

Figure 8.—Another variation of this: Let A B be the greater, and C D the lesser semi-axis, as before; take the straight line H I, equal to the greater semi-axis, A C or C B; from I H cut off I K, equal to the lesser semi-axis, C D, and divide H K into two equal parts at I; then place the joint rule C E F in the following manner, viz., make C E and E F each equal to H L, or L K; the part C E being moveable round the centre, C, of the ellipsis, and the two rules C E and E G being moveable round E; now let C E and E G coincide with C D, and the point F to coincide with C, and consequently G with D; then move the point F towards A, keeping it in the semi-axis C A; and when C E and E F come in the same straight line, the point G will have described the quadrant of an ellipsis; the lesser axis (*see Figures* 7 and 8) is equal $2 \times$ F G, and the greater $= 2 \times$ C E $+ 2 \times$ E G.

Demonstration.—*Figure* 7, No. 2. Draw G I parallel to C F, cutting C E at I, and draw E L perpendicular to C F, meeting C B at L; produce C E to H, and make C H = C B; join H G, and produce it to K.

Now by the general demonstration, accompanying the article CYLINDER, we have $CB^2 : CD^2 :: AK \times KB : KG^2$; but by the property of the circle $KH^2 + AK + KB$; therefore $CB^2 : CD^2 :: KH^2 : KG^2$; consequently $CB : CD :: KH : KG$, a property of the ellipsis.

But C E is the half sum of the two axis, and C I, or F G, equal to the lesser axis; then I E, or E G, is equal to the difference between the half sum of the two semi-axes and the lesser semi-axis; therefore I E = half the difference between the two semi-axes, and I H = the whole difference; consequently I E = E H.

Then because I G is parallel to C F, we have $EC : EF :: EI : EG$; but $EC = EF$; therefore $EI = EG$; and because $EI = EH$, E G is also equal to E H: then since the angle E P G is a right angle, the angles P E G and E G P, are together equal to a right angle; but the angles E G H and G E P are alternate; therefore $EGH = GEP$; add to each of these equal angles, the angle E G P, then will $EGH + EGP = GEP + EGP$ equal to a right angle; consequently I G is parallel to C K, and the triangles C K H and I G H are similar.

Therefore $CH : CI :: KH : KG$; but $CB = CH$, and $CD = CI$; $CB : CD :: KH : KG$, the above property of the ellipsis.

Method VII.—*Figure* 9. Find the foci E and F, as in Methods I. and II. let the ends E and F of two rules F I and E K be moveable, the one round E, and the other round F, and let each be equal in length to A B, the greater axis, intersecting each other at E; let the ends I and K be connected by a bar, I K, equal in length to E F, so as to be moveable round the points I and K; then if the point I or K, be carried round G, the whole instrument will be in motion, and the point A will describe the curve of an ellipsis.

Demonstration.—Join E I; then, because the triangles I K E and I F E have the two sides, I K and K E, equal to the two sides E F and F I, and the base I A common to both, the angles I K E and I F E are equal; therefore the sides I H and H E are equal; therefore $IF = AB = EH + HF$, which is a property of the ellipsis.

Method VIII.—Another method will be found under the article CONE, by the equal divisions and intersections of straight lines.

Method IX.—*Figure* 10. *To find any number of points in the curve.*—On the transverse axis, A B, describe a semicircle: take as many points in the circumference of the semi-circle, as may be necessary for constructing the elliptic curve; draw straight lines perpendicularly to the axis cutting it, and let one of these lines, C D, pass through the centre; let E F be any other perpendicular, cutting the axis in F, and let C G be the lesser semi-axis; find the point H, so that F H may be a fourth proportional to C D, C G, F E, and the point H will be in the curve of the ellipsis required: in the same manner, a point may be found in each of the other perpendiculars. The finding of points in the curve by this method being entirely in proportion, the whole may be very readily obtained, by making $IK = CD$, I L, equal to the lesser semi-axis of the ellipsis; join K L; on I K make I l, e m, I n, equal to the perpendiculars; draw l o, m p, n q, parallel to K L, cutting I L, at o, p, q; then I o, I p, I q, are the ordinates of the ellipsis, to be applied respectively upon the perpendiculars, from the greater axis. This may very easily be described by means of the proportional compass, or the sector.

Method X.—*Figure* 11. Let A B be the greater axis, C D the lesser semi-axis. On the diameter A B, describe the semi-circle A E B, and with the radius C D describe the semicircle F D G; take any number of points, h, i, &c. in the circumference A E B, and draw h C, i C, &c. cutting the semicircle F D G, at k and l; from the points h, i, &c. draw lines h m, i n, &c. perpendicularly to A B; also from the points k, l, &c. draw lines k m, l n, &c. parallel to A B; then the points m, n, &c. are in the elliptic curve. When the points for half the curve are found, the corresponding points for the other half will be readily obtained, by producing the perpendiculars to the other side of C B, and making the ordinates on the one side equal to those on the other.

Method XI.—*Figure* 12. *Any two conjugate diameters,* A B *and* C D, *being given, to describe an ellipsis through points found in any diameter, taken at pleasure.*—Through D draw P Q parallel to A B; from D draw D F, perpendicular to P Q; make D F equal to E A, or E B, upon F; with the distance F D, describe the circle n D k; through the centre, E, draw the lines P E N, t E M, s E L, indefinitely cutting the tangent P Q, at P, t, s, &c.; join P F, t F, s F, &c. cutting the circle n D k, at the points n, m, l, &c.; also join E F, if necessary, and draw n N, m M, l L, &c. parallel to it, cutting the diameters N N, M M, L L, &c. at N, M, L, &c. and these points will be in the curve of the ellipsis required: if the diameters are produced to the opposite sides, at N, M, L, &c. and the distances E N, E M, E L, &c. are made respectively equal to their opposite corresponding distances E N, E M, E L, &c.; then the points N, M, L,

on the under side of the diameter A B, will also be in the curve.

This method may be very easily applied in perspective: by having the representation of a diameter of an original circle perpendicular, and that of another parallel to the picture, we have a diameter and double ordinate: the diameter of the ellipsis, or representation, is the diameter of the circle perpendicular to the intersecting line of its plane; thus it is only finding the conjugate diameter, and drawing as above.

Figure 13.—*The axes* A B *and* C D *of an ellipsis being given, to describe its representation by means of circular arcs.*—Draw B P parallel and equal to E C; bisect it at 1; draw 1 C, and P D, cutting each other at K; bisect K C, by a perpendicular meeting C D at O; on O, with the radius O C, describe the quadrant C G Q; through A and Q draw Q G, cutting the quadrant at G; draw G O, cutting A B at M; make E L equal to E M, and E N equal to E O; from O, through M and L, draw O G and O K; from O, complete the arc G K; from N, with the same radius, equal to the distance N D, describe the opposite arc H I; from M with the radius M G, describe the arc G H, at the extremity of the longer axis; and lastly, from L, with the same radius, equal to L B, describe the opposite arc K I; then A G C K B I D H A is the representation required, made to pass through eight points in the curve.

Figure 14.—*To find the representation of an ellipsis, by means of circular arcs, passing through twelve points in the curve* (*a more accurate method than the former*) *the axes* A B *and* C D *being given.*—Draw A 3 parallel to E C; divide it into three equal parts; draw 2 *c* and 1 *c*; divide A E also into three equal parts, and through the points 1, 2, draw D Q and D P, cutting the former in Q and P. Bisect C P by a perpendicular, meeting C D, produced at S; and join P S, cutting A E at X; make E W equal to E X, and E U equal to E S; draw P X S, O W S, K X U, and L W U. Bisect P Q by a perpendicular, meeting P S at F, and draw Z F parallel to A B. With the radius F Q describe the arc Q Z, cutting F Z at Z; join Z A, and produce it to meet the arc at Q Z, at *y*: join *y* F, cutting A B at V; make X I equal to X F, also W H, and W G, equal to X F; make E T equal E V, and draw I V R, H T M, and G T N; then, with the centre S, and distance S C, describe the arc P O; with the centre U and distance U D, equal to the former, describe the opposite arc K L; with the centres I, F, G, H, describe the arcs K R, P Q, N O, and L M; and, lastly, with the centres V and T, describe the arcs Q R and M N, at the extremity of the longer axis; and A C B D is the representation passing through the twelve points A, Q, P, C, O, N, B, M, L, D, K, B, as required.

This method differs so little from a true ellipsis, that it may be used in preference to any instrument for describing the curves of very large arches of bridges, and in finding the joints of the stones, as was the practice of the celebrated French engineer Perronet.

Another method of describing an ellipsis, by means of an instrument, constructed upon the principle of the oval turning lathe.—As we have never seen any investigation of this method, upon simple principles, the Author offers the following to the public, which has only been given in his *Mechanical Exercises.*

Definition.—If there be any plane figure, and two inflexible straight lines at right angles to each other; and if the plane be fixed to an axis at right angles thereto; and if the two inflexible lines be made to coincide with the plane, and be so moveable on its surface, that one of them, which we shall call *the primary line*, may always pass through two fixed points in the plane, and through the point where the plane is intersected by the axis; and if the other transverse line be made to pass or slide along a given point, which is not attached to the plane, but would remain stationary, even though the plane were in motion; and if a secondary plane be fixed to the inflexible lines parallel to the primary plane; then if the axis be carried round while the point in the transverse line is at rest, the primary plane will also be carried round, and every point in it will describe the circumference of a circle: the secondary plane will likewise be carried round, and perform its revolutions in the same time as the primary plane and the axis, but being immoveably fixed to the rectangular lines, they will cause it to have both a progressive and retrogressive motion, in the direction of the primary line, in each revolution; and, lastly, if another point at rest be held to the surface of the secondary plane while in motion, it will either describe an ellipsis, a circle, or a straight line. Hence the describing point will always be at the same distance from the centre, or point where the axis intersects the primary plane.

The eccentricity of the ellipsis, or the difference of the axis, will be double the distance between the stationary point in the transverse line and the axis.

Instead of the stationary point, a circle may be placed with its centre in this point, and its plane perpendicular to the axis, and instead of the inflexible line moving backward and forward upon two fixed points in the plane, the diametrically opposite parts of the circumference may always touch a pair of parallel lines on the revolving plane.

Illustrations.—*Figure* 15. Let A B and E F, No. 1, 2, 3, 4, 5, 6, 7, 8, be the two inflexible lines intersecting each other in I, at right angles, and let C D be the two fixed points. Let A B be denominated *the primary line*, and E F *the secondary line*, and let the lines A B and E F at right angles, taken as a whole, be called *a transverse;* also, let C represent a primary point, and let the describing point be taken at G, in the line drawn through C D produced; now, in all positions of the chuck, the primary line A B is always upon the point C, and E F upon D. Having premised this in general, suppose, before the machine begins to start, that E F, No. 1, the secondary line, coincides with E G, and the point G with *o*, *o* being in the plane of the figure to be described; then because A B always passes through C, the points I and C will be coincident, A B being then at right angles to E F. Let us now suppose the motion to commence, and let it perform an eighth part of a revolution, as at No. 2, the describing point G, still remaining in the same position with respect to C and D, viz., in the right line C D G; then the point *o* will be at a distance from the point G, and a part, G *o*, of the curve will be described by the fixed point G, and the point I will be above the line C D G; now let the motion proceed, and describe another eighth, as at No. 3, then, the point *o* being always in the line E F produced, E F will be at right angles to the fixed line C D G, and A B coincident with C D G and the point which was last at G, will now be at I. In like manner, when another eighth has been performed, as at No. 4, the point *o* has performed three-eighths of a revolution, the point 1 is in a line drawn from the point C perpendicular to the fixed line C D G, and the point 2, which was at G, in No. 3, is situated between 1 and G. In this manner, by continuing the motion, the whole curve will be generated. No. 5 shows the curve when half a revolution has been described; No. 6, five-eighths; No. 7, six-eighths, or three-quarters; and No. 8, seven-eighths.

Here it may be proper to observe, that the angles performed by the revolution of the machine, are very different from the corresponding angles, formed by lines drawn from the centre of the ellipsis to the describing point, and to the extremity of the curve at its commencement.

From what has been said, it is easy to conceive, that the

operation of elliptic turning is nothing more than that of the ellipsograph, or common trammel, with this difference, that in the operation of turning, the ellipsis is described by moving the plane, and keeping the point steady, but in forming the curve by the ellipsograph, the plane of description is kept steady, while the point is in motion. The transverse A B E F is the same as the grooves in the trammel-cross, and the line C D G the trammel-rod: here the cross and plane of description move round together, but fixed to each other, and the trammel-rod C D G is held still or immoveably confined: in the trammel, the board and cross are fixed together, and held while the trammel-rod C D G moves with the points C and D in the grooves.

To set this machine, therefore, it is only to make C D equal to the difference of the axes.

Figure 16.—No. 1, 2, 3, and 4, show the relation between the foregoing diagrams and the chuck. Let K L M N be the face of a board representing the plane, which is fixed to the axis of the machine; and let O P Q R be another board, made to slide in the board K L M N: each two points, O and K, L and P, M and Q, N and R, coinciding at this moment, K L M N will therefore represent a wide groove in the board; as this groove may be of any width, we may conceive the breadth to be very small, or nothing; it may therefore be represented by a groove, or by the line A B parallel to K N and L M, and in the middle of the distance between them. Instead of supposing the point D always moving backward and forward on the line E F, we may suppose a circle, or the end of a large cylindric pin, moving in a very wide groove, T U V W, across the slides O P Q R. Now, all the differences between these diagrams and those in the former Plate, are only wide grooves in place of lines passing longitudinally through the middle: for the line A B is always conceived to move reciprocally from one side to the other of the board K L M N; and it is the same thing whether one straight line slide longitudinally upon another fixed line, or whether a bar of any breadth move in a groove of the same breadth, or whether a straight line in reciprocal motion always pass through two fixed points.

No. 1, shows the chuck, as in the first diagram of the last Plate: No. 2 as No. 2, No. 3 as No. 3, and No. 4 as No. 4, of the said Plate. Any farther explanation is conceived to be unnecessary.

Problem 2.—*An ellipsis,* A B D C, *being given, to find the transverse and conjugate axes.*

Draw any two parallel lines A B and C D, cutting the ellipsis at the points A, B, C, D; bisect A B at e, and C D at f; draw G $e f h$, cutting the curve at G and H; bisect G H at I, which gives the centre; from I, with any radius that will cut the curve, describe a circle, $k l n m$, and join $k l$ and $m n$; bisect $k l$, or $m n$, at o or p, and draw Q o I p R, meeting the curve in Q and R: then Q R is the greater axis; draw S T at right angles therewith, meeting the curve in S and T, and S T will be the lesser axis.

Problem 3.—*Any diameter,* A B, *being given, and an ordinate* C D, *to find the conjugate diameter of the ellipsis.*

Draw C I perpendicular to A B; bisect A B in F, and draw F H parallel to C D; on F, with the distance F A, or F B, describe the semi-circle A I B, cutting C I at I; make A E equal to C I, and draw E G parallel and equal to C D; through G and A, draw A H, cutting F H at H, then F H is the semi-conjugate diameter.

This problem is useful in perspective, in the representation of the circle: for, having the representation of a diameter of the circle perpendicular to the intersecting line, and the representation of a diameter of the circle parallel to it, the former representative diameter of the circle will be a diameter of the ellipsis, and the latter will be a double ordinate of the same; find the conjugate diameter by this problem; then, having the two conjugate diameters, the curve may be described as in *Method* XI; or the axis may be found as in the next problem, and thence this curve described.

Problem 4.—*Any two conjugate diameters,* A B *and* C D, *being given, to find the axis.*

Through D draw E F parallel to A B, and D I perpendicular to E F; make D I equal to M A, or M B; with the radius I D describe from I the arc g D l, and join I M, which bisect by a perpendicular, meeting the tangent E F at N; with the distance N I describe from N a semi-circle, E I F; join E M and F M, which produce to H and K; and join I g E and I l F; parallel to I M, draw l L and g G, cutting H E and K F at G and L; make M H equal to M G, and M K equal to M L; then will G H and K L be the two axes required.

In like manner, if G H had been a diameter, its conjugate would have been thus found: produce H G to E, and join E I; draw E V at right angles to E I; then draw g G, and complete the rest as before.

This problem may be readily applied in perspective; for, by the last problem, two conjugate diameters will be found, and having the two diameters, the axes may be found by this, and the curve be described geometrically by an elliptic compass, or by traversing the curve with an ivory, pasteboard, or strong paper slip.

Problem 5.—*An ellipsis and its foci* F *and* G *being given, to draw a tangent through a given point,* H, *in the curve.*

Join F H and G H, and produce the latter to I; bisect the angle I H by the straight line L H, and L H is a tangent to the curve.

This problem is very useful in masonry, for finding the joints of elliptic arches. Thus, find a tangent in the curve, at the lower end of the joint, and from the point of contact, draw a line perpendicular to the tangent; and the line thus drawn will be the joint.

Problem 6.—*Two conjugate diameters,* A B *and* C D, *and the centre,* H, *being given, to draw two tangents to the ellipsis, from a given point,* E, *without the curve.*

First, let the point E be in D C, produced; make H I equal to H C, and join I E; through C draw C K, parallel to I E, cutting H A in K; make H L equal to H K, and through L draw F G parallel to A B; find the extreme points F and G, by *Problem* 3, and draw E F and E G, which are the tangents required.

But if the point E be in neither of the diameters, A B or C D, when produced, draw a line from the given point E, through the centre, so as to be terminated by the curve; and the portion thus intersected will be a diameter; then find a conjugate to this diameter, as in *Problem* 4.

This problem will be very useful in the perspective representation of a cone, for drawing the contour of the sides with the utmost exactness; the diameters being found by the preceding problem.

Problem 7.—*To describe an ellipsis similar to a given one* A B C D, *through a given point,* P, *having the same centre, and the axes in the same lines.*

If the two axes, A D and B C, are not given, find them as in *Problem* 4; and the point E, where they intersect, is the centre; through the given point P, draw F E, to meet the curve in F; join A F and F B; parallel to F A draw P G cutting A E at G; and parallel to F B draw P H, cutting E B at H; then will E G be the greater semi-axis, and E H the lesser semi-axis.

Problem 8.—*Through the angular points,* A B C D, *of a given rectangle, to circumscribe an ellipsis, which shall have its axes in the same ratio as the sides of the rectangle.*

Draw the diagonals A C and B D, cutting each other at S, the centre; through S draw E F and G H, respectively parallel to A B and A D; upon S, with the radius S I, equal to the half of A D or B C, describe the quadrant I K L, cutting E F at L; bisect the arc I K L at K, and through K draw M N parallel to E F, cutting the diagonal B D at N; join I N, and through B draw B G parallel to it, cutting G H at G, and make S H equal to S G; join N O, and through B draw B F parallel to it, cutting E F at F; make S E equal to S F, and E F and G H are the two axes; then the curve may be described by any of the methods shown in Problem 1.

Problem 9.—*A trapezium,* A B C D, *being given, to inscribe an ellipsis therein.*

Produce the sides B A and C D to Q; also the sides A D and B C to R; draw the diagonals A C and B D, meeting each other at F; through F draw R I H, cutting the sides of the trapezium at I and H; also, through F draw Q E G, cutting the other two sides of the trapezium in E and G; bisect I H at N, and E G at M; draw Q N P and R M P; join I P, to which produce K: make P K equal to P I; draw G L parallel to C D, cutting I K at L; then I K is a diameter bisected by P, the centre, and L G is an ordinate.

This problem might have been constructed, as in the *Principles* (see Vol. I. *Problems* XVIII. XIX. and XX.) by having one of the points of contact given; but it is here much simplified, and reduced into one problem, by which it is much better adapted to perspective.

Problem 10.—*To find the area of any segment of an ellipsis.*—Let $t =$ the greater axis,
$c =$ the lesser,
$y =$ D H, the ordinate,
and $x =$ A D, the abscissa.

Then by the property of the curve, we have $y = \frac{c}{t} \times x\,(a\,x - x^2)^{\frac{1}{2}}$ but $\frac{c}{t} \times \dot{x}\,(a\,x - x^2)$ is a fourth proportional to t, c, and $\dot{x}\,(a\,x - x^2)^{\frac{1}{2}}$ for $t : c :: \dot{x}\,(a\,x - x^2)^{\frac{1}{2}} : \frac{c}{t} \times x\,(a\,x - x^2)^{\frac{1}{2}}$; and since $\dot{x}\,(a\,x - x^2)^{\frac{1}{2}}$ is known to be the fluxion of the semi-segment of the circumscribing semi-circle A E B, (see the article SEGMENT;) therefore, as the transverse axis, or the diameter of the circumscribing circle, is to the conjugate, or diameter of the inscribed circle, so is the area of the semi-segment of the circle to the area of the elliptic segment A H D; but the ordinate F D of the circle is to the ordinate H D of the ellipsis, as the diameter of the circumscribing circle is to the diameter of the inscribing circle; therefore, circular and elliptic segments upon the same base, and between the same parallels, are to one another as their bases, when the greater axis of the ellipsis is equal to the diameter of the circumscribing circle.

It is therefore evident, that, whether we know the specific measure of the greater axis of the ellipsis, or the diameter of the circumscribing circle, or not, we still can obtain the area of the elliptic segment, by a circular segment; provided it be known, that the greater axis of the ellipsis is equal to the diameter of the circle. In architecture, this circumstance is frequently known: suppose, for example, that in a groin, one side is the segment of a circle, and the other the segment of an ellipsis; it follows, from the construction of the groin, that both the vertical diameter of the circular side, and the vertical axis of the elliptic side, are equal; and therefore, if the width of each side of the groin, which is the chord of its arc, be given, and the height of the arch, we have nothing more to do than to find the area of the circular section or side, and the area of the elliptic side will be found by the rule of proportion. For practical use, take the following rule:

First.—*To measure the circular segment.*—To two-thirds of the area of the base, multiplied by the height, add the cube of the height, divided by twice the base of the segment, and the sum is very nearly the area of the circular segment then *To find the area of the elliptic segment,* say, As the chord of the circle is to the chord of the ellipsis, so is the area of the circular segment to the area of the elliptic segment.

Example.—What is the area of the elliptic end of a groin which rises 5 feet, and extends at its base 15 feet, supposing the base of the circular end to be 18 feet?

2 × 15 = 30, twice the length of the segment.

18	5
15	5
90	25
18	5
3)270	3,0)12,5
90	4.166, &c.
90	

180 two-thirds of the product of the base and height.
4.166 cube of the height, divided by twice the base.

184.166 area of the circular segment.

Then 18 : 15 : : 184.166
15

920830
184166

18)2762490(153.471 the area of the elliptic segment
18

96
90

62
54

84
72

129
126

. 30
18

12

To have wrought this example according to the series, would have been too operose for practical purposes.

The above method for finding the area of the segment of a circle, was discovered, or invented, by the author, in the year 1794, and published in his *Principles*, in 1795.

It is evident, that whatever takes place in the segment, must also occur through the whole curve; therefore, in an ellipsis having its greater axis equal to the diameter of a circle, it will be, As the diameter of the circle is to the lesser axis of the ellipsis, so is the area of the circle to the area of the ellipsis.

Example.—What is the area of an ellipsis, the greater axis of which is 24, and the lesser 18?

```
      24
      24
      ——
      96
     48
    ————
     576
   .7854
    ————
    2304
   2880
  4608
 4032
 ———————
```

452. 3904 the area of the circumscribing circle.

Therefore 24 : 18 : : 452.3904

```
                 18
           ————————
           36191232
           4523904
           ————————
24)8143.0272(339.2928 the elliptic area.
   72
   ——
    94
    72
    ——
    223
    216
    ———
      70
      48
      ——
      222
      216
      ———
        67
        48
        ——
        192
        192
        ———
```

But the proportion of 18 to 24, is as 4 to 3: therefore the above might have been considerably abridged; we were, however, desirous of working the operation at full length, as would unavoidably happen in case of incommensurable numbers, in order to compare it with the following operations.

Now let us try whether we cannot find a more practical rule for the area of an entire ellipsis, than that above.

Let $p\,d^2$ be the area of a circle circumscribing an ellipsis, where

$p = .7854$, and $d =$ the diameter of the circle or greater axis of the ellipsis,

and $c =$ the conjugate, or shorter axis;

then we have $d : c : : p\,d^2 : \frac{p\,d^2\,c}{d} = p\,d\,c$ the area of the entire ellipsis; we have therefore the following neat rule.

Multiply the two axes together, and the product by .7854, and this second product will be the area.

Suppose now, for the sake of comparison, that we take the former example, viz., the greater axis 24, and the lesser 18.

```
     24
     18
   ————
    192
    24
   ————
    432
  .7854
  —————
   1728
 2 160
34 56
302 4
———————
```

339 . 2928 area of the ellipsis.

In the same manner, may the half, or the quarter, be found, viz., by multiplying the two dimensions together, and the product by .7854.

Example.—In a semi-ellipsis upon the greater axis. Let the greater axis be 24, as above, and the lesser semi-axis 9 the area is required.

```
 24          .7854
  9            216
 ———         ———————
216          4 7124
             7 854
           157 08
           ———————
```

169.6464 = the area of the semi-ellipsis, which is half of the entire area before shown.

Example in a quadrant.—Let the greater semi-axis be 12, and the lesser semi-axis 9, the area is required.

```
 12          .7854
  9            108
 ———         ———————
108          6 2832
            78 540
           ———————
```

84. 8232 the area of the quadrant of the ellipsis, being one quarter of the area of the entire ellipsis, in the foregoing example. The area of an ellipsis is a mean proportional between the area of the circumscribing and inscribing circle.

For $p\,t^2$ is the area of the circumscribing circle; and $p\,c^2$ is the area of the inscribing circle:

Now $p\,t^2 : p\,t\,c : : p\,t\,c : \frac{p^2\,t^2\,c^2}{p\,t^2} = p\,c^2$; and therefore the proposition is manifest.

To find the periphery of an ellipsis.

Let $a =$ the greater semi-axis A C;
$c =$ the lesser semi-axis;
$x =$ the distance C D from the centre, the abscissa;
$y =$ D H, the ordinate;
$z =$ E F, the arc:

then will A D $= a - x$ and D G $= a + x$, therefore A D $\times$ D G $= a + x \times a - x = a^2 - x^2$.

Then by the property of the ellipsis,

A C^2 or C B^2 : C G^2 : : A D $\times$ D B : D H^2; that is

$$a^2 : c^2 : : a^2 - x^2 : y$$

consequently $y^2 = \frac{c^2}{a^2}(a^2 - x^2)$

and therefore $y = \frac{c}{a}(a^2 - x^2)^{\frac{1}{2}}$

and $\quad \dot{y} = \frac{-c\, x\, \dot{x}\, \frac{1}{2}}{a(a - x^2)}$ Therefore $\dot{z} =$

$$(\dot{x}^2 + \dot{y}^2)^{\frac{1}{2}} = \frac{\dot{x}\left(a^2 - \frac{a^2 - c^2}{a^2} \times x^2\right)^{\frac{1}{2}}}{(a^2 - x^2)^{\frac{1}{2}}};$$ but by substituting d for $\frac{a^2 - c^2}{a^2}$ in this last expression we obtain $\frac{\dot{x}\,(a^2 - d\,x^2)^{\frac{1}{2}}}{(a^2 - x^2)^{\frac{1}{2}}}$ for the value of $\dot{z}$. But

$$\frac{\dot{x}\,(a^2 - dx^2)^{\frac{1}{2}}}{(a^2 - x^2)^{\frac{1}{2}}} = \frac{a\,\dot{x}\left(1 - \frac{d\,x^2}{a^2}\right)^{\frac{1}{2}}}{(a^2 - x^2)^{\frac{1}{2}}} = \frac{a\,\dot{x}}{(a^2 - x^2)^{\frac{1}{2}}} \times \left(1 - \frac{d\,x^2}{a^2}\right)^{\frac{1}{2}}.$$

Then by throwing the factor $\left(1 - \frac{d\,x^2}{a^2}\right)^{\frac{1}{2}}$ into an infinite series, we obtain $\dot{z} = \frac{a\,\dot{x}}{(a^2 - a^2)^{\frac{1}{2}}} \times \left(1 - \frac{d\,x^2}{2\,a^2} - \frac{d^2\,x^4}{2.\,4\,a^4} - \frac{3\,d^3\,x^6}{2.4.6\,a^6}\ \&c.\right)$ But the fluent of $\frac{a\,\dot{x}}{(a^2 - x^2)^{\frac{1}{2}}}$ is equal to the corresponding arc, E F, of the circumscribing circle. Therefore, taking A equal to the circular arc, we obtain the fluent of $z = \text{A} - \text{B}\frac{d}{2\,a^2} - \text{C}\frac{d^2}{2.4\,a^4} - \text{D}\frac{3\,d^3}{2.4.6\,a^6}$ where $\text{B} = \frac{a^2\,\text{A} - x\,(a^2 - x^2)^{\frac{1}{2}}}{2}$, $\text{C} = \frac{3\,a^2\,\text{B} - x^3\,(a^2 - x^2)}{4}$, $\text{D} = \frac{5\,a\,\text{C} - x^5\,(a^2 - x^2)^{\frac{1}{2}}}{6}$ &c., but when x becomes $= a$, then $(a^2 - x^2)^{\frac{1}{2}} = 0$, consequently the values B, C, D, become only as follows, viz.,

$$\text{B} = \frac{a^2}{2}\text{A}$$

$$\text{C} = \frac{3\,a^2}{4}\text{B} = \frac{3\,a^2}{4} \times \frac{a^2}{2} \times \text{A} = \frac{3\,a^4}{2.4}\text{A}$$

$$\text{D} = \frac{5\,a^2}{6}\text{C} = \frac{5\,a^2}{6} \times \frac{3\,a^2}{4} \times \frac{a^2}{2} \times \text{A} = \frac{3.5\,a^6}{2.4.6}\text{A}$$

These values being substituted in the above series, give the quadrant $z = \text{A} \times \left(1 - \frac{d}{2.2} - \frac{3\,d^2}{2.2.4.4} - \frac{3.3.5\,d^3}{2.2.4.4.6.6}\right)$ &c. Now by putting $\text{B} = \frac{d}{2.2}$, $\text{C} = \frac{3\,d^2}{2.2.4.4}$, $\text{D} = \frac{3\,.\,3\,.\,5\,d^3}{2.2.4.4.6.6}$, &c. we obtain $z = \text{A} \times \left(1 - \frac{d}{2^2} - \text{B}\frac{1.3.d}{4^2} - \text{C}\frac{3.5.d}{6^2} - \text{D}\frac{5.7.d}{8^2}\right)$ &c. Therefore, to find the circumference of an ellipsis, we have the following

RULE. Multiply the circumference of the circumscribing circle by the sum of the infinite series $1 - \frac{d}{2^2} - \text{B}\frac{1.3.d}{4^2} - \text{C}\frac{3.5.d}{6^2} - \text{D}\frac{5.7.d}{8^2}$, &c.

Example.—Required the periphery of an ellipsis, the transverse axis of which is 50, and the conjugate 40, then will $d = 1 - \left(\frac{40}{50}\right)^2 = 1 - \left(\frac{4}{5}\right)^2 = 1 - \frac{16}{25} = 1 - .64 = .36$

Therefore 2) .36 = d

2) .18

.09 = $\frac{d}{2.2}$ = A

1

.09

3

.27

.36 = d

162

81

4) .0972

4) .0243

.006075 = A $\frac{1.3\,d}{4.4}$ = B

3

.018225

5

.091125

.36 = d

546750

273375

6) .03280500

6) .00546750

.00091125 = B $\frac{3.5\,d}{6.6}$ = C

5

.00455625

7

.03189375

.36 = d

19136250

9568125

8) .0114817500

8) .00143521875

.00017940234375 = C $\frac{5.7\,d}{8.8}$ = D

7

.00125581640625

9

.01130234765625

.36 = d

6781408593750

3390704296875

.0040688451562500

10) . 0040688451562500
10) . 0004068845156250
. 00004068845156 25 = D $\frac{7 . 9 d}{10 . 10}$ = E
9
. 0003661960640625
11
. 0040281567046875
. 36
0241689402281250
120844701140625
12) . 001450136413687500
12) . 000120844701140625
. 000010070391761 71875 = E $\frac{9 . 11 d}{12 . 12}$ = F
11
. 0001107743093789 0625
13
33232292813671875
11077430937890625
. 0014400660219257 8125
. 36
00864039613155468750
432019806577734375
4) . 000518423767893 2812500
7) . 0001296059419733203125
7) . 0000185151345676171875
. 000002645019223 9453125 = F $\frac{11 . 13 d}{14 . 14}$ = G

Therefore, these terms collected, are as follow:

A = . 09
B = . 006075
C = . 00091125
D = . 00017940234375
E = . 00004068845156 25
F = . 00001007039176171875
G = . 000002645019223 9453125

Therefore . 0972190562062981640625 = the sum of the negative terms, which therefore being taken from 1.
. 0972190562062981640625
leaves . 9027809437937018359375 for the sum of the series.

Therefore . 90278 0943
50
45.1390 47150
3.1416
270 8342 8290
451 3904 715
1 8055 6188 60
4 5139 0471 5
135 4171 4145
141.8088 3052 64400 = the periphery of the ellipsis required.

But as this rule would be much too laborious for practice, we must content ourselves with some easy method of approximation: It will be very serviceable, however, in comparing the results obtained by such approximations, in order to ascertain the degree of dependence that may be put on them. Let us therefore try the following Rule, for the periphery of the whole, the half, or the quadrant of the curve.

RULE.—Multiply the square root of the half sum of the squares of the two axes by 3.1416, and the product will be the circumference, nearly.

Example.—Let the greater axis be 50, and the lesser 40 as before: the entire periphery is required.

50	40
50	40
2500	1600
1600	

2) 4100
20.50 (45.27692, the root.
16
85) . 450
425
902) . 2500
1804
9047) . 69600
63329
90546) . 627100
543276
905529) . 8382400
8149761
9055382) . 23263900
18110764
.5153136

45.2 7692
3.1416
271 6 6152
452 7 692
1 8110 7 68
4 5276 9 2
135.8307 6
142.2419 7 1872

The above, though agreeing only in the two first places of figures, is sufficiently near for most practical purposes in measuring; the difference in four places of figures is only four more than the truth.

The investigation of this rule is as follows:
Let t = the greater axis,
and c = the lesser,

then $p\left(\frac{t^2 + c^2}{2}\right)^{\frac{1}{2}}$ expresses the rule;

but $p\left(\frac{t^2+c^2}{2}\right)^{\frac{1}{2}} = p\,t\left(\frac{1}{2}+\frac{c^2}{2\,t^2}\right)^{\frac{1}{2}}$

and since $d = 1 - \frac{c^2}{t^2}$

we have $\frac{c^2}{2\,t^2} = \frac{1-d}{2}$

therefore $p\,t\left(\frac{1}{2}+\frac{c^2}{2\,t^2}\right)^{\frac{1}{2}} = p\,t\left(\frac{1}{2}+\frac{1-d}{2}\right)^{\frac{1}{2}} = p\,t$

$\left(1-\frac{d}{2}\right) = p\,t\left(1-\frac{d}{2^2}-\frac{d^2}{2^3.4}-\frac{d^3}{2^4.8}-\frac{5\,d^4}{2^5.16}\right)$

&c. = the periphery; but the true periphery $= p\,t$

$\left(1-\frac{d}{2^2}-\frac{3\,d^2}{2^2.4^2}-\frac{3.3.5d^3}{2^2.4^2.6^2}\right)$ &c. Now this series agrees with the former in the first and second terms, and differs in the third only $\frac{d^2}{64}$; the rule is therefore an approximation.

The rule now delivered is still too long for practical uses; let us therefore try the following:

RULE.—Multiply the half sum of the two axes by 3.1416, and the product will be the periphery, nearly.

Example.—The same still as the preceding, viz., 50 and 40.

```
   50            3.1416
   40                45
  ----          -------
 2)90            15 7080
  ----          125 664
   45           --------
                141.3720 the periphery.
```

This rule is exceedingly easy, and sufficiently near for all practical purposes, where the eccentricity of the ellipsis is not very great. It gives the periphery nearly as much below the truth as the preceding rule is above; and, consequently, where great accuracy is required, if the result be found by both methods, the half sum will be exceedingly near. To show this by an example:

The result by the first rule	142.241971
The result by the last rule	141.3720
	2)283.613971
The half sum of both	141.806985

which is very near the truth, as it agrees in five places of figures with the result by the series.

ELLIPSOGRAPH, an instrument usually constructed of brass, for describing a semi-ellipsis at one movement of the index. *See* ELLIPSIS, *Problem* 1, *Method* 3.

ELLIPSOID, a solid, generated by revolving a semi-ellipsis round either of its axes. This solid is understood by some to be the same as spheroid. *See* SPHEROID.

ELLIPTIC ARCH, a portion of the curve of an ellipsis, employed as an arch. This curve has some advantages over circular arcs, in bridge-building, as it leaves a greater space at the haunches for the passage of vessels, and, consequently, saves a considerable quantity of materials in the construction.

ELLIPTIC COMPASSES. *See* ELLIPSOGRAPH.

ELLIPTIC CONOID, the same as ELLIPSOID.

ELLIPTIC WINDING STAIRS, a winding stair, having an ellipsis for its plan. *See* STAIRS and WINDING STAIR.

EMBANKMENT, a large body, mound, or bank of earth, constructed or thrown up in different ways, according to circumstances. Embankments are of various kinds, according to the purposes for which they are designed, as RAILWAY EMBANKMENTS, which carry a line of railway over valleys and low ground at the elevation required for the level of the rails; CANAL EMBANKMENTS, for confining the water of a canal or reservoir, or upon which a canal or aqueduct is formed; and EMBANKMENTS constructed with the view of guarding, protecting, and defending lands on the borders of the sea, rivers, and lakes, from being inundated and injured by them, and for reclaiming lands from the sea.

We shall treat first of the latter description of embankments. These are of different kinds and forms, according to the nature of the situations and the materials of which they are constituted. In embanking against the sea and large rivers, where the slopes next them are naturally gentle and easy, they are mostly of the earthy description, being well put together, and covered on the surface with turf cut from the tough sward of the land in the neighbourhood; but in cases where the banks, borders, and shores, are steep and bold, they are usually of a more hard and solid nature: as of stone, brick, gravel, sand, shells, and other similar substances, laid closely in some sort of tenacious material, such as clay or mortar, and other matters of the same quality. Timber is also frequently employed in their construction, in a variety of forms.

In works of this sort, very much depends upon the form in which they are constructed, and the nature and management of the materials made use of. In respect to the first, it may be remarked, that banks of these kinds are commonly constructed with too narrow bases for the heights which are given them; from which circumstance, the sides which are opposed to the effects of the water become too steep and upright; consequently, in cases of high tides or floods, they are utterly incapable of resisting their weight, which has equally a lateral and downright pressure. Besides this, there is another disadvantage attending this method of forming them, which is, that the floods, as well as the tides, in ebbing and flowing, have a more continued action on one part than would be the case, if the slopes were more gentle and gradual: consequently, they have a much greater tendency to break down and destroy the superficial parts of the banks. With some variations in the forms, most of the embankments in this country are, however, made in this way. They may succeed in some particular instances; but, in general, it is found that breaches are frequently taking place in them, from the effects of the sea or floods, which are not capable of being filled up or repaired without considerable difficulty and trouble; and which, if suffered to continue even for a short space of time, endanger the whole embankment.

The common form of embankment is shown at *Figure* 1, and the improved form pointed out at *Figure* 2.

The angles or slopes of these sorts of works are made very different in various cases; but that shown in the above figure seems, in general, well calculated for the purpose of resisting the impression of heavy tides, or the waters of floods. The greater breadth they have, in proportion to their height, the more effectual they must be in resisting the power of the waters which come upon them. In regulating the heights of embankments, it is necessary to ascertain the greatest depth of water at the highest tides or floods; making the summits of them about two feet higher than the points to which they rise at such times. By some, a less height than this above the highest mark of the tides or floods has, however, been considered sufficient; but it is always proper to be on the safe side, as the consequences of an overflow are very serious.

In forming embankments with stones, or other similar

materials, which, as has been seen, is essential in bold steep banks or shores, it is necessary that they be laid in proper materials, and be closely jointed next the sea, or the rivers, so as to be fully capable of resisting the entrance of water. Great care is requisite in doing this, or the bank will not stand, for the water, insinuating itself between the openings, will sink down among the stones, softening and loosening the clayey or earthy matters underneath, by which portions of them will be forced out and washed away. Hollows being formed in that way below, the stones naturally sink down; and the waters, rushing into the cavities with considerable impetuosity, quickly displaces others, and the whole embankment is soon destroyed. This very frequently takes place with the heads thrown across rivers, and such paved or causewayed banks as are formed with the view of protecting and preserving bold and open shores. Such shores are especially liable to be undermined and carried away by the washing operation of the waters which come against them. In order to render the embankments perfectly secure in such cases, they should be laid with good mortar, and be pointed with a strong cement. A good coat of gravel, in some cases of this kind, is even found far superior to paving with stones.

It sometimes happens that rivers, near their mouths, form shallow estuaries, and occupy much ground which might be usefully employed. In this case, an entirely new outlet may sometimes be made, through which the river may at once discharge itself into the sea; and the whole course will, probably, be soon filled up by the deposition of soil and mud brought in by the tides; for it is the current which clears the channel, and when this is taken away the channel soon fills up. In the course of a short time the old mouth of the river will be so filled up as scarcely to admit the tide; and an embankment across it may lay a large fertile track of land quite dry.

In constructing embankments of the quay, or other similar kinds, a mortar formed from powdered unburnt lime-stone and coarse sharp sand is employed; the whole being pointed with puzzolana earth, by which they become as solid as rock, and fully resist the effects of water. The lime of particular sorts of lime-stone is found more proper for forming this sort of mortar-cement than that of others: thus, that found at Dorking, in Surrey, is supposed to constitute the most durable substance of this kind of any in the kingdom; and has been employed in many works near London. And an excellent sort of lime-stone, for the same purpose, has likewise been discovered near Worsley, in Lancashire, which is there termed *Sutton lime.*

An excellent cement for this use, which hardens under water, may be composed by having four parts of blue clay, six of the black oxide of manganese, and nine of carbonate of lime, submitted to a white heat, and then well incorporated with sixty parts of sand, and as much water as may be necessary to form it into a mortar. *See* CONCRETE.

It is invariably found, in examining the shores of the sea, and the banks of rivers, that such as have easily and gently declining slopes from their beds to their borders or banks, and those which are formed in a steep upright manner, of rocky materials, such as are shown at *Figures* 3 and 4, are the least exposed to injury from the effects of the waters: the two former being the most secure when spread over or coated with good coverings of sand or gravel, or uniformly turfed over quite down to the water-side with the sward of a tough old pasture. The strength and firmness of their banks are in proportion to the extent of the slope; and their durability depends on that of their being made uniform on their surfaces, both in respect to hardness and smoothness: as in the former case, from the great length of slope, the flows and decreases of the waters act more momentarily on their different parts, and their greater weight renders their banks more firm; while, in the latter case, by the equality of their surfaces, the power of the water is rendered the same on one part as another, and no obstacles are left for the producing of eddies, or other means of forming holes or breaks in them.

In the latter, or those of the bold, upright, rocky kind of banks, their strength chiefly depends on the resistance of the large quantity of materials by which they are backed, and not on the manner in which they are disposed, as in the former case; and their durability, on that of the uniform compactness of texture in the parts opposed to the effects of the waters: as, where these have fissures in them, or are softer in some parts than others, the waters are liable to enter and break down the banks in time, according to the particular nature of the cases.

It is, therefore, of importance, that the modes and forms of embankment, which are thus naturally presented, should be improved upon by art. It is evident, that if a cut were formed behind the embankment, as in *Figure* 5, at the letter *x*, the shores or banks, though, in this case, as it were, detached from the land, would be found equally strong, and capable of resisting the pressure of the waters, as in their original state. Hence, if a mound or bank were formed, and placed out at the distance of one, two, or three miles from the shore or other embankment, within the bed of the sea or other waters, as at *y* in the same *Figure*, it would be equally capable of resisting them as in the former instance, and not more liable to be broken down by their pressure than in its former station; and would also defend them as completely from the intermediate space of land, as it did before from the narrow trench. Consequently, on this principle, vast tracts of land may, in different parts of the kingdom, be obtained by judicious embankments.

Though the shores of bold steep coasts may not afford examples equally capable of being followed with advantage as the above, they nevertheless suggest useful hints for the purpose of defence, in cases of bold, abrupt, broken shores, constituted of earth, or of that material and rocky substances intermixed. It readily presents itself to the mind, that the raising a good perpendicular stone wall against such banks, renders them nearly as strong and lasting as those formed by nature of steep solid rocky bodies. This sort of walled bank is exhibited at *Figure* 6; but though this method may be practised, in cases of the above kind, with great advantage, it is not, by any means, applicable in general to rivers; as, with them, the waters, during the periods of floods, stand in need of room to spread, which is the great use of giving their banks a sloping form; while, in this way, it would have the effect of doing more injury than was the case before. The increased rapidity of the current, caused by its being so confined, doing greater damage to the banks. Instances may, however, happen in which it may be had recourse to with propriety, in defending a part of the bank of a river, without giving it a sloping direction, or for protecting one part of a bank at the risk of that which is opposite to it; but well-constructed piers, in such cases, are preferable, and attended with less expense to maintain. But instead of these, art may suggest one that may answer in some respect more perfectly; as, in place of bringing together such a mass of earthy or other substances, as may be proper for constructing such banks as are shown at *Figures* 1 and 7, it may be more advantageous to have one formed, such as is shown at *Figure* 8, the side of which, next the water, forms, with the base, an angle of about 45 degrees. This will be capable of bearing all the weight or pressure of water that can possibly be brought upon it, equally well with that of *Figure* 1, except

that the operation of the tides would break the superficial part of the side next the sea, unless prevented by coating it with some durable substance, such as paving stones, bricks, or other similar materials.

Banks of various kinds, between this and the first natural kind, may be invented, differing only in the degree of inclination which they have towards the sea; that which slopes in the highest degree, as *Figure* 1, having the surface covered over with sand or gravel; and that which has the least slope, as *Figure* 8, may be covered with pavement; the different intermediate slopes being protected by materials which have a quality between the two, such as coarse gravel, chalk-stones, brick, and sand. The embankment, shown in *Figure* 9, is wholly constructed of a sandy loam deposited upon a soil of the same quality; but as it would not, for some time after being formed, be sufficiently impervious to water, a column of clay is carried upright in the middle, from the clayey substratum of the soil underneath, as is shown at $x\ x$, in the section. This is called *Puddling*.

In cases where the shores are of a very sandy nature, embankments may be made wholly of a sort of wicker-work. Thus three or four rows of paling are put down, of different heights, and the vacant spaces between them well filled, by forcing in furze, brush-wood, or even straw, as represented at *Figure* 10. These substances, by detaining the mud and sand, as the tide passes through them, or during high floods, soon forms a sort of embankment, such as that shown in the above representation. It should afterwards be covered with some plant, which is capable of binding and giving it solidity, such as the *elymus arenarius*. An embankment, so constructed, would continue, during extraordinary tides, to retain still larger quantities of the sandy materials, until, ultimately raised above the range of the highest floods, a safe bank would be formed. By banks formed in this way, large quantities of land might be gained in a very few years, in different parts of the rivers Severn, Humber, Frith, &c.

In all cases of embankment, however they may be formed, tunnels and sluices of a proper kind, with valves towards the sea or rivers, must be occasionally placed, according to circumstances, so as to permit the water that may be collected within to pass away, and that of the sea or rivers, to flow up, with different intentions in the view of improving the land.

The utility of projecting points is very considerable, in different cases, on the sea-coasts and rivers, in defending the bays and inlets of the former, as well as guarding the banks of the latter, by diverting their streams or currents to the opposite sides. Hence arises the formation of piers, which become highly beneficial in defending embankments, as well as the borders of rivers and brooks. In the first of these cases, they may generally be constituted and coated over with the same sort of material as that of which the embankment is formed; while, in the latter, they should be formed of some sort of stony matter, being constructed in such a way as to decrease in every direction as they advance outwards, as represented in *Figure* 11. In each of these cases, they are, however, capable of being constituted of brush wood, secured by means of stakes, often with more perfect success. And it frequently happens, that a simple rude wicker-work fence, of not more than three or four yards in length, may be fully sufficient for the purpose. Embankments formed of stone, unless constructed in the manner represented at the above figure, are apt to cause eddies below them; while those formed of brush-wood cannot have this effect.

It is obvious, that considerable attention must be required in deciding the most proper situations for constructing this sort of projection in, and the distances to which they should extend into the rivers; as a too extended projection may be highly dangerous to the opposite bank, and of course do harm, instead of being beneficial; while not carrying them out sufficiently far may prevent the effect which is wanted. In cases where piers are to be formed of stone, as in rivers where the bottoms are of a rocky nature, the plan represented at *Figure* 11, is a good one, as it will scarcely cause any eddy, and be nearly similar to that of the wicker-work, in the effect which it produces. Different works of these several kinds have been constructed in the northern parts of the island with much success.

Proper Materials for Embankments.—It will be obvious, that different sorts of materials may be made use of in different situations and kinds of works of this nature, with more advantage than others, both in so far as duration and expense are concerned.

Those steep upright embankments, which are constructed with the view of protecting bold shores, or coasts, and the banks of particular rivers, may probably be best formed of good brick, rubble, or ashlar work, in the manner of a wall, as seen at *Figure* 6, in the Plate, the materials being laid in the strongest mortar that can be made. But where this is not the case, they may be built in the common way, and pointed with puzzolana earth, or what is termed the Roman cement, prepared by Messrs. Parker and Co., London. Concrete has been used most successfully and extensively for the purpose of embankments, as we have shown under that article.

The different kinds of sloped embankments may be formed either with common earthy materials, clay, mud, or a mixture of these several different substances; and any other matters which are capable of uniting into a solid, firm, compact mass, may be had recourse to for the same purpose. Where the sides next the sea or other waters form angles of from 20 to 30, or even 35 degrees with their bases, they may be coated with sand, the shells from the sea, or coarse gravel from the borders of the shores. And stones, broken down to uniform sizes of a few pounds in weight, may be employed in a similar manner. Where none of these substances can be procured in sufficient abundance, a method practised in Holland, of covering them with such perishable materials as mats, reeds, straw, bark, and others of the same nature, may be had recourse to; but these are obviously disadvantageous, as requiring very frequent renewal. They might likewise be protected by a low fence of brushwood fixed in an erect manner all along at the bottom of the bank, of an equal height, as tending to break off the violence of the waves. Another method might also be employed, which is that of covering the whole front of the bank with brushwood, either made into bundles, or in the manner of wicker-work, or fixed down in a neat manner by means of long poles and strong hooked stakes. And farther, they may be laid in the form of a causeway, with stones in moss, or covered with wicker-work applied upon the mossy material when spread out over the bank. Many other modes also may be adopted under particular circumstances.

In all cases where the sides and slopes towards the sea constitute angles of from 35 to 45 degrees with their bases, as in *Figure* 8, recourse may be had to stones of the flag kind, as coverings, which should be jointed with cement mortars formed in some of the ways we have mentioned above. And where these sorts of stones cannot be provided, if clay can be found, proper kinds of bricks may be made, and used in the same way as the stones. Where the slopes or inclined planes are from 40 to 45 degrees, it is frequently more cheap and economical to have them covered with stones of about six or eight pounds in weight, applied to the thickness of a foot and a half, or nearly two feet; or these may be used on

a bed of common moss of three inches, or of peat-moss of the flow kind, of six inches in thickness, spread upon the banks, only to the thickness of six or eight inches. Stones of these kinds may likewise be formed into a sort of causeway, or be laid in strong clay, and their surfaces jointed with lime or a strong cement mortar, which has the property of quickly hardening, and of enduring the operation of the air and tides, which alternately act upon it.

There may likewise be cases in which it may be the most advantageous practice to have the sides next the sea or rivers protected by coverings of wood only, in which case, larch may be the most proper, or such others as are durable, having their surfaces covered over with pitch and some sort of sharp sand. And old sail-cloth, or oil-cloth pitched and coated over with sand in the same manner, or even thin plates of metals, have been suggested as useful in particular instances.

In a paper read before the Institution of Civil Engineers in May, 1841, the Hon. Mr. Stewart gave a very interesting account of the application of peat to the purpose of building "sea walls." The author described some embankments constructed with it on the estates of his brother the Earl of Galway, to reclaim various portions of land, to the amount of many hundred acres, and stated that it had been found to answer extremely well, for several reasons, the most prominent of which were, that the blocks of peat, when well rammed down, grew together, thus forming a complete "puddle" wall; and that from its spongy nature it was not liable to crack in dry weather like clay, when any portion of it was in water, as moisture was in that case drawn up to all parts of it.

It is evident that great quantities of land might in many situations be obtained from the sea and large rivers, by the forming of proper embankments. Some notion of this may indeed be formed by a careful examination of such lands as lie along their shores and banks, by ascertaining the distances to which the waters ebb out at common tides, as it is found by experience, that at least one-half of the extent of land, thus uncovered in any particular situation, may be gained; hence, throughout the whole kingdom, it could hardly be estimated at a less quantity than from two to three millions of acres, but it is probably much more than even the last quantity, if it were capable of being ascertained with any degree of accuracy or correctness.

Importance of embankments.—When the extent and the value of the lands which are capable of being gained by these means are fully considered, there can be no doubt of their being of the greatest consequence to the interests of the country. It has been well remarked by a late writer on this subject, that there are numerous places in the kingdom where vast improvements may be effected by the judicious application of these means. Vast tracts of land of the best kind may not only be gained from the sea, but likewise from the large rivers and lakes, besides the beneficial consequences which must necessarily arise from the prevention of such rivers from overflowing their banks, and injuring the level grounds in their vicinity by such inundations. In some cases, it is supposed, that by raising a bank of only three or four feet in height, at a very small expense, some thousands of acres might be prevented from being overflown, the crops from being carried away, and much other mischief from being produced. In other instances, the forming of very trifling banks might be the means of obtaining much extent of country, which in its present state is of but very little value; yet so indifferent are people in general about improvements of this description, that though immense tracts are year after year overflown, and the most dreadful devastations committed, they have recourse to no means of prevention; nay, even though the sea itself, says the writer, as if to rouse them from their inaction, presents to their view twice every twenty-four hours, large tracts that might by proper means be made of very great value, yet these repeated invitations are disregarded, and no attempts are made to possess what might, in many cases, be so easily and so advantageously acquired. It is certainly extraordinary and unaccountable that the acquiring of distant possessions should be eagerly sought after, and considered of so great importance to us as a nation, when the addition of land in our own country by the reclamation of it from the waters, must be in every point of view so much more valuable.

The acquisition of additional territory at home should, therefore, be more attended to, and have more expense bestowed upon it than has hitherto been the case. In particular situations, indeed, a few active and enterprising persons have taken advantage of the opportunities which have been presented; as in the counties of York, Lincoln, Cambridge, and others, many hundred thousands of acres have been gained by embankments. In Norfolk, too, a considerable extent of land has been gained in this way. In the neighbourhood of Chester, the River Dee Company have likewise gained several thousands of acres from the sea, which have since been divided into different beautiful farms, the whole of which pay in rent more than 2,000 pounds per annum. And in Holland the whole country has, in a great degree, been obtained by these means.

It is stated by Mr. Beatson, in the second volume of *Communications to the Board of Agriculture*, that large sums have been expended in some places by individuals with a view of guarding against inundations, but, owing to the embankments they have made being injudiciously placed, and as badly constructed, the desired effect has not always been produced, particularly in the northern parts of Cheshire, on the banks of the river Mersey, where works of this kind have been thrown up at a great expense, which, from the manner of their being placed, may, in some cases, by confining the course of the river, do more harm than good. By the appearance of that part of the country, so far as he could judge from the cursory view he had of it, it seemed to him that the inundations from that river might have been effectually prevented at a much easier rate, if a proper method had been taken at first; but from a certain ill-judged and mistaken tenaciousness of property, the embankments are constructed so close upon the sides of the river, that, in many places, it is confined to a space not more than 20 yards over. Owing to this, and to an aqueduct across the river, with only one arch instead of two, which it ought at least to have had, the water sometimes, in great floods, rises, he was informed, to the height of about 20 feet above its ordinary level, and overflows the embankments, although now, by frequent additions, they are about that height. Instead of 20 yards, had these embankments been 80 or a 100 yards distant from each other, and the river widened in the narrowest places, one-third or one-fourth of their present height would have been quite sufficient. They would have been much easier made, and less liable to damage by the floods; a great deal of money also would have been saved, not only in the first construction, but in keeping the banks afterwards in repair. The space of ground between the embankments and the river thus left, would have produced the richest pasture, or meadow-hay, by its frequent manurings with the fertilizing particles left upon it, when flooded by the swelling of the river; and in those places, if any, that are unfit for pasture or hay, willows or other aquatics might have been planted to great advantage;

and thus it might have been of more value perhaps than at present, while the interior grounds would have been more effectually secured from the ravages of sudden floods. Notwithstanding the general indolence shown in most parts of the country, respecting the acquisition of land by embanking, and the seeming aversion that most people have to engage in such undertakings, there have been, however, some ingenious and enterprising projectors, whose ideas upon that subject have soared far beyond the bounds allotted to common understandings. From the speculations of such people, the most important advantages are sometimes produced; and surely the man who is possessed of a speculative turn of mind, and who considers no obstacles insurmountable, is a much more useful member of society than he who is perpetually starting difficulties against every new project, and is for having all things remaining *in statu quo*, that is, for leaving the world as he found it.

The idea of reclaiming land from the sea, for example, would have appeared to a torpid genius of this kind, as a matter too visionary for sober-minded men. A thousand difficulties would have started up at such a proposal; and obstacles, which to a more expanded mind, would seem perfectly practicable to overcome, would have presented to him impediments insuperable.

What would such anti-projectors think of proposals to exclude the sea entirely from extensive bays, many miles across, and exposed to the full sweep of the winds and the waves? Such was the proposition to carry a railway embankment across Morecambe Bay, and the estuary formed at the mouth of the Duddon, the embankments on Lough Foyle in Ireland, and other similar works.

That there are many large tracts of land in different parts of the kingdom, both on the sea-coasts and on the sides of lakes and rivers, easily attainable, there cannot be the smallest doubt. It is, therefore, an object worthy of the attention of those who are so fortunate as to possess property of this nature, to have it ascertained by persons of experience in such matters, how far the acquisition of additional portions of land may be adequate to the expense which it may be necessary to incur in procuring it. But embankments are important in other views than those of gaining ground by them. When rivers are concerned, one material advantage is the deepening of their courses, by which vessels of greater burden than they admitted formerly, may be permitted to navigate them.

And farther, as embankments become more frequent on the borders of rivers and sea-shores, the intervening distances may become a sort of bays, in which accumulations of shell, mud, sand, gravel, and other matters, may take place by the influx of the tides; and these, however difficult they may be at first to embank, will in time be as easy to perform the work on, as the natural bays and creeks are at this period. In this way many rivers, which in their present state are eight or ten miles in width at their junction or influx with the sea, may in the course of years be reduced to less than half these distances. Consequently, such embankments would be equally beneficial to the proprietors of land, and the merchant or manufacturer, as many rivers would become more easily navigable, and those obstacles which interrupt their mouths be wholly removed.

In embanking against the encroachments of the sea, it is necessary to ascertain, with great accuracy, the maximum height to which the water rises; the methods of doing this have been already shown. But as new works of this sort, especially where the banks are large, are liable to subside too much, it may be a proper precaution to take the levels frequently for some time after they are completed, in order to guard against any mischief which might arise in this way. Where the banks are low, this is not, however, so necessary as in higher ones, as the settling is always more or less according to their height; in low banks it will of course be very little. In the making of such embankments, it is scarcely possible to lay down any general rule in regard to their size or dimensions, as these must be directed by situation and circumstances, under the management of an expert engineer. In cases where the embankment to be formed is to exclude the sea from a piece of low marshy ground, over which it only flows at spring-tides, the work is easy, and capable of being accomplished at no great expense. But where it is intended to reclaim a portion of land which is covered every tide, in some bay or creek, or on the sides or windings of some large river in which the tide ebbs and flows, the business will be in some degree more difficult, according to the depth and rapidity of the current of the water. And where it is proposed to exclude the sea from an exposed situation at the mouth of a river, or in a bay, or inlet, which is uncovered every tide, the operation will be the most difficult and expensive of all, according as it is exposed to prevalent winds, and the depth of the water to be resisted. Each of these situations, therefore, requires a different method of management.

The business of embanking against the sea, when at any considerable distance within high-water mark, is not only the most tedious, but at the same time the most difficult; as, when the materials are not very good and the work not well performed, the force of the water at every flowing of the tide will quickly undo all that has been effected, especially if the soil be of a sandy nature, as is often the case in such situations. If it be a strong clay, as is sometimes the case in marshy places, there will be the less risk of its being washed away. In sandy situations it has been advised by some to lay bundles of straw or reeds well fastened down, or any other impediment, to hinder the soil from being carried away by the ebbing tide. Where a sufficient supply of good strong turf cannot be had, other expedients may be tried; but where such turf can be provided, as is the case in most marshy situations, and where the embankment required is not to exceed the height of four or five feet, it is best to finish the slope with good turf as expeditiously as possible, as the work proceeds; that is, supposing the length of 30, 40, or 50 feet or yards of it can be completed in a tide, it is better to finish that length to its intended height, than to trace out or begin a greater extent than can be finished before the tide returns, by which a great deal of the soil might be carried away, and much of the work demolished, which is not so likely to be the case when the slope is finished. Turf which contains the roots of bent or rushes is very good for this use.

In commencing a work of this kind, however, the first thing to be done is to strike out the intended line of it, setting out the breadth at the base, also the width of the excavation or trench to be made in the inside, from which most of the materials that compose the bank are to be taken: this trench serving also as a drain to keep the grounds within dry. There should also be trunks or sluices at different parts of it, to shut off themselves against any external water, and to open when the tide ebbs, to let out any water from within. The width of it should be proportioned to the quantity of materials required from it, for the raising of the embankment, as eight, ten, or fifteen feet wide, and three or four feet deep, leaving a *berme*, or space, between the edge of the trench and the inner bottom of the embankment. If the soil be strong, one foot or eighteen inches will be sufficient for this purpose; but if loose or sandy, three or four feet at least will be required. The more easy and gradual the external slope is made, the less sudden the resistance against the sea will be, as has been seen above, and of course the embankment be less liable to

injury; this slope should therefore be formed according to the exposure of it to the winds and tides: a contrary opinion has, however, been held by some engineers, and the formation of upright walls properly faced has by them been considered better adapted to resist the action of the water. *Figure* 12, is supposed to be a section of an embankment in which the base or horizontal line $g\ h$ should at least be three times the perpendicular height $h\ i$; but $l\ m$, the inside slope, need not be more than three-fourths of the perpendicular height, that is, nine inches for every foot of rise. The inside slope should be faced with turf likewise, laid with the green side downwards, as in common sod walls. Some expert sodders can finish this sort of work extremely neat by setting the sod on edge, according to the slope intended to be given, and with proper mallets and beetles ramming the earth hard behind, which consolidates the work as it advances, and tends to render it durable. As soon as the first or lower course is finished, the upper edge of the sods is pared with a sharp knife quite even, by laying a rule to them, and then they go on with the second course, which they finish in the same manner, and thus proceed until the whole height is completed, which, when properly finished, has a smooth and beautiful appearance, not a joint between the turfs being seen. Where turf is used in covering the outside slope, it should all be laid with the grass uppermost, as already noticed, and be well beaten down with a flat sod-beetle for the purpose, and in order the better to secure them, it may be proper to drive small stakes, about eighteen inches in length, through every sod. In cutting sods for this use, they should be taken up in a careful manner, and be all traced by a line of the same breadth; their edges being cut as even as possible, that they may make the closer joints, which will tend very much to their security, until they are grown properly together. In laying the different courses of such sods, care should also be taken that the joints of the one be covered by the other, in the manner that good brickwork is made.

Where it is proposed to reclaim a piece of land, upon which the sea ebbs and flows every tide, to a greater depth than in the foregoing case, as in a creek, or on the side of a large river, a different mode of proceeding must be pursued, according to the soil, and the nature of the materials to be employed. Where plenty of stones can be readily procured, a bank may be formed of them, with a mixture of clay, either by means of land-carriage, or, which in some instances is better, by conveying them in flat-bottomed boats, or punts, and throwing them over-board until the bank is formed. Where stones cannot be easily had, clay, or other materials proper for the business, may be thrown in, in sufficient quantity, in the same manner, with perhaps nearly equal success. It is supposed that most of the embankments in Holland were formed in this way, the clay dug from the canals being made use of for the purpose. In either case it is requisite to fix up strong poles before the work is begun, as guides for laying down the materials. Proper sluices must likewise be laid in suitable direction for taking off the back-water when the tide ebbs, under the inspection of the engineer. Much, in all cases of this sort, depends on a skilful engineer, who is capable of suggesting and contriving various means of facilitating the business, and of obviating the difficulties that may arise in its execution. A person of real genius is often capable, by his different contrivances, of rendering the accomplishment of a great undertaking comparatively easy, which to others would be almost impracticable, or carried on at such a heavy expense as to counterbalance the advantages to be drawn from it. In cases of the kind just noticed, he might suggest the erection of stages or platforms, in such a manner as to carry on the work at all times of the tide, which would be an immense saving, as the delays caused by the tides in this sort of business are both tedious and expensive. Waggons might likewise be contrived in such a way as to carry on such platforms large quantities of materials at once, which could be easily emptied and filled; and at the same time be drawn by machinery, in such a manner as to save much labour and expense, both in carriage and tidework.

There is another species of sea embankment, which is, perhaps, the most important of any; as there are few estuaries, or mouths of rivers, in which large tracts of land may not be gained by it. The shoals or flats formed at the entrance of such rivers, are mostly composed of the richest and most fertilizing particles, brought down from the towns and circumjacent country through which they pass. Such shoals and flats may, therefore, under proper management be in most cases readily converted into the most fertile plains. In these situations the first object is that of collecting the whole river into one stream, and preventing its overspreading a wider extent than is merely sufficient for its discharge; or it may be better, perhaps, to alter its course altogether, and cause it to be discharged at some other outlet. It has been found by experience, that where the course of a river is changed in such a manner as to make it discharge itself into the sea at a different place to that where it did before, the former place will in a few years, by the continued accumulation of sand and mud brought in at every tide, be so choked up, and raised above its former level, as to form of itself, in the course of time, a bank, that with a very little assistance, will exclude the sea; for as the current of the river before carried away all that sediment which the motion of the waves naturally stirred up, from its being now removed, it is obvious that all or most of the muddiness will not only be carried farther up the old channel of the river, but a great part of it be deposited there as the tide recedes. It has been found that in spring-tides and particular winds, this sediment is deposited in larger quantities than at other times, and on making a perpendicular cut in the ground under reclamation, the different layers are found to be so distinct, that those made at spring-tides can be easily distinguished from the rest. This curious fact is well deserving of the attention of all those who have lands situated at the mouth of rivers, as there may in many such situations be considerable tracts gained at a very light expense. But though this fact may exist in some places, as has been proved by experience, nevertheless it is supposed that the effect cannot be the same in all situations. Where there is a great extent of flat or muddy shores, the motion of the waves will no doubt stir up the mud and sand, and carry great quantities of them along with the current on the flowing of the tide; and when the tide ebbs, though some of the lighter particles will be carried away again, yet it is reasonable to suppose the heavier ones will be left behind. If the shores are bold and rocky except just near the entrance of the river, there will be less of this mud; but on such shores there can, indeed, be little or no occasion for embanking, unless perhaps in some creeks, narrow at the entrance and spreading out wide above. If the sea were excluded from such creeks, a great deal of land might probably be gained.

In the marshland district of the county of Norfolk, lying between the rivers Wyn and Ouse, immense tracts of the most rich land, such as is composed of the muddy depositions left by the tides and floods, which is there called *silting*, have been obtained by means of embanking. This kind of work has sometimes been undertaken by the tenants on a low piece of marsh, in consideration of having the land free for twenty-one years. But in these cases the banks have often been very

imperfectly made, not having cost more than forty shillings a rod. And those which were constructed by the landlords were indeed frequently but little better, being mostly deficient in not having slope enough given them towards the water. Count Bentinck, and his son, who succeeded him in the estates, undertook the drainage of the marsh lands upon a scale never practised in that part of the island before, and by their successful operations have increased the old estates by more than 1,000 acres.

The base of the embankment, in this case, is about 50 feet, the slope to the sea 36 feet, forming an angle, of about 25 or 30 degrees. The crown is 4 feet in width, and the slope to the fields 17 feet, in an angle of about 50 degrees; the slope towards the sea being very nearly turfed over. The first expense incurred in forming this bank was £4 per rod, but a very high tide coming before it was finished, not only made several breaches, but occasioned an additional height and slope to be given to several different parts, in order to bring it to the dimensions mentioned above, all of which made the gross expense to amount to about £5 the rod. The whole cost was something more than £5,000. The expense of the houses, farm buildings, and other things, was about as much more, for five new farms, which was a greater expense than was necessary, as the land would have let as well in two or three as five farms. Supposing, therefore, the expense at £10,000 and the new rental at £1,000 a year, it is just 10 per cent for the capital laid out. The expense here, however, seems to have run too high, when the necessary repairs of the bank are taken into the account. The representation, given at *Figure* 22, in the Plate, fully explains the nature of the embankment formed in this case.

In another new embankment, in which 273 acres of marsh land, and 18 of bank, were gained, the men were paid 4s. 6d. a floor of 400 cubical feet, finding wheeling planks, barrows, trussels, &c. When it is thus formed, the front slope is sodded, for which they are paid in addition 4s. a floor of 400 square feet, earning from 5s. 6d. to 7s. a day, and there is some little further expense necessary for beating it down in a firm manner. The whole of the expense of the bank, sluice, and every thing else, was about £3,300. The land was immediately offered to be rented at four pounds an acre for four years, or three pounds an acre for six years; which, in the former case, would amount to £4,368 in that length of time, or 1,000 guineas more than the whole of the capital laid out on the undertaking.

On this coast the operation of *silting* up, or raising the surface of the marsh-land by the repeated depositions of muddy matters from the sea, is performed in a more rapid manner than in many others; and the little hollows and creeks are found from experience to silt up much faster where the tide-waters are speedily taken off by proper cuts and channels formed for the purpose, than where the contrary is the case.

One of the most extensive reclamations of land in England, is the large tract of country known by the name of the Great Bedford Level. This great expanse of rich and fertile country is bounded by the high lands of the counties of Norfolk, Suffolk, Cambridge, Huntington, Northampton, Lincoln, and the Isle of Ely, and contains upwards of 300,000 acres of fen-land, beyond which are about a dozen very large marshes also similarly reclaimed. The drainage of the whole level is effected by innumerable dikes and drains of all sizes communicating with, or gathered together into three great channels, forming the main outfalls into the sea. One of these outfalls is at Boston, in Lincolnshire; one at Wisbeach, in Cambridgeshire; and the other at Lynn Regis, in Norfolk.

In Holland, however, is exhibited the most prominent illustration of the successful redemption of land from the sea; and probably in no part of the world has it been carried to so great an extent. Indeed, the whole country has been rescued, as it were, from the waves of the ocean, and has been secured and held only by the constant care and superintendence of the persevering conquerors.

There is little doubt that the inhabitants of Holland were obliged, in the first instance for their own preservation, to erect barriers against the encroachments of the sea. On the invasion of their country by the Danes and Normans, the latter soon discovered the superiority of these lands to those adjacent to them, and at once applied all their energies to the proper reclaiming of so fertile a property. Thus, by the steady perseverance of ages, has Holland become pre-eminent for the extent of her drainage works, though the manner in which their embankments are constructed is very far from equal to similar works executed in this country. It is said by those who have made it their business to examine the mode of making these banks, that in those made of stone, the materials are not economically distributed, but are heaped so confusedly on each other, as not only to weaken the bank, but occasion great waste. They have, however, a very ingenious method of facing their banks where there is a scarcity of stone, with straw, formed into ropes, about an inch or two in thickness, laid in regular courses. These courses fit closely together from top to bottom, and are fastened down to the bank with wooden *falks*.

In Ireland the attempt to bring into cultivation the immense tracts of bogs or flats partially covered with water, a few years ago attracted the public attention; and a board of commissioners was appointed to inquire into the nature and extent of the bogs in Ireland, and the practicability of reclaiming them.

These commissioners have published reports containing much interesting and instructive matter, exhibiting the present state of the wastes in certain districts, and evincing clearly the practicability of converting them at a comparatively small expense, into rich arable and pasture land.

On the north and west coasts of Ireland there are a great number of deep bays or inlets of the sea, presenting great facilities for embanking. Amongst these the estuaries called Lough Swilly and Lough Foyle, in the counties of Donegal and Derry, seemed to offer to some enterprising speculators a tract of land peculiarly adapted for embanking.

Sir John Macneill having been consulted on the scheme for the drainage of these loughs, employed Mr. J. W. Bazalzette to make the necessary surveys for the purpose, and the latter has furnished to the Institution of Civil Engineers a valuable paper on the subject from which the following observations have been extracted.

Lough Foyle is described by Mr. Bazalzette, as not entirely insulated from the Irish Channel, but as having a narrow mouth communicating with it. Above this mouth the waters spread over a wide tract of land, and then again contract into a narrow channel. The effect of the tide rising through so small a passage has been to scour the *narrows*, and throw up the deposits on the sides of the Lough. By the accumulations of years these deposits have at last become immense banks of rich alluvial soil extending for some miles and covered only at high water. To reclaim this land it was proposed to construct an embankment or sea-wall, a little below low-water mark, for fourteen miles in length, by which about 25,000 acres of land would be enclosed.

Lough Swilly is less extensive than Lough Foyle, but presents greater difficulty in the construction of the works, from the scarcity of the necessary materials. It is wider at its

mouth (which opens into the Western Ocean,) than in any other part, and in its whole extent is extremely exposed to the winds. It was proposed to construct here three embankments, the first 1,100 yards, the second 1,133 yards, and the third 633 yards in length. The position of these banks being fixed by careful measurements and soundings, the proposed method of formation was as follows :

Each bank was to be 4 feet in perpendicular height above the highest spring-tides, which here rise to 18 feet : and to have a slope on the sea-face of 3 to 1, except in the most exposed part, where the slope was to be 4 to 1. The materials available for the work were stone, clay, earth and gravel, taken from the adjoining lands, and the banks were to be faced with rough stones on both sides, laid as close as possible with the edge outwards, in courses not exceeding 4 feet in height. In the centre of each bank was to be built a culvert of masonry, with proper sluices and flood-gates. These culverts were to rest on a foundation made by driving piles into the soil, which from its alluvial character could not be depended upon in itself. The sluices being self-acting, the drainage would be effected in the following manner. At high water, it being supposed that the whole of the *slob* (as it is termed in Ireland,) is covered on the receding of the tidal water, the sluices would shut of themselves, retaining the water within the banks. When the flood-tide came on, the pressure on the sluice-gates from within, would prevent their opening to admit it, and the retained water would soon evaporate, leaving the rich slob dry, and to be in a short time fit for agricultural purposes.

The extent of the slob thus enclosed by these three walls would be about 2,000 acres, and the value of it may be estimated by the fact that a large quantity of land has already been reclaimed near this part of the Lough. This land now lets at £5 per acre, and is considered the richest soil in the neighbourhood. Indeed, in every case, where a proper selection of land has been made, and the works performed judiciously, similar success has been the result.

It has been remarked by Mr. Beatson, whose observations on this subject we have before noticed, that in the lakes or *mires* of the north, and the *Loughs* of Scotland and Ireland, the business of embanking is both simple and easy. In these situations the waters generally subside during the summer months, rising considerably in winter, and whenever the season is very wet. In particular cases the extent of surface which is overflown in the winter season, so far exceeds that which it covers during the summer, that it would be an object, and sometimes a considerable acquisition, to confine the water within its summer boundaries, or to cut off some of its parts. To accomplish this the principal outlet must be carefully examined, and be considerably widened and enlarged ; which will prevent the water from rising so high as was formerly the case. Where the levels will not admit of much depth being had, or where the ground is of a rocky nature, and would of course be difficult and expensive to deepen, the breadth should be increased as much as possible, and all obstacles cleared away, that the water may run freely in a shallow stream. Where it is required to ascertain with exactness, or, to fix with certainty, the future limits of the water, a section of the greatest quality running out during a flood should be taken. Suppose this section, for example, be 10 feet in width and 4 feet in depth, by making it 40 feet in width, the same quantity of water will not rise above 1 foot : consequently, by this means alone, 3 feet in height will be gained all round the lake, which, in case of embanking it, would be a great object. During the summer season, when the water is lowest, is the most proper time for carrying on these, as well as other embankments. When, however, any materials are to be brought from a distance, they may be laid down, or prepared at other seasons, with the exception of turf, which should always be used as soon as possible after it is cut. The manner of constructing embankments of this kind may be sufficiently understood, from what has already been said in the other description of embankments: observing, however, as a general rule, that when the materials on the spot will answer the purpose, they should invariably be made use of, although at the expense of digging a trench larger and deeper than would otherwise be necessary. It should constantly be attended to, in executing all sorts of embankments, that the greatest care be taken to make them perfectly firm and solid, by continually beating them, and examining them carefully, during the whole of the time they are in a state of being formed.

The following account of embankments on the Continent, is taken from the "Dictionary of Terms of Art," part of the very useful rudimentary treatises published by Mr. Weale.

"On the banks of the Po, two sorts of dykes are used to prevent the river from overflowing during the winter, or the flood season. They are called 'in froldi,' when immediately upon the banks of the river, and 'in golene,' when at any considerable distance, as it is sometimes found advisable to allow the river to spread over a large surface of the adjacent valley, either for the purpose of admitting it to deposit the mud in suspension, or to allow it to lose its torrental character. The maintenance of the works of these dikes is confided to the government engineers, who are under the control of a syndicate of the proprietors of the property most liable to be affected by inundations. When the river passes from one state to another, as from Piedmont to Modena, a mixed com mission is charged with the joint superintendence.

"The Haarlem lake, besides the very remarkable steam-engines described by Mr. Dempsey, merits observation for the extensive works executed for the defence of the land, and for the canals reserved for the navigation. The enclosure dike is 50,000 metres long, or rather more than 31 miles. It has two outfall dikes, which serve for the navigation, 9,000 metres, about $5\frac{1}{2}$ miles ; one half of which is 40^m (131 feet 2 inch) wide at the bottom or floor line ; the other 43^m 20 (141 feet 10 inches.)

"The ordinary tides are at the flux, 2 feet 4 inches above the scale or datum line at Amsterdam ; at the reflux 2 feet 8 inches below the same datum : the difference between high and low water is then, on the average, about 5 feet. With violent winds from the N. W., however, the tides rise sometimes 6 feet 6 inches above the average. The tides of the Y, near the lake, are $+ 16^c$ (or $6\frac{1}{2}$ inches) and -23^c (or 9 inches), giving a total variation of 1 foot $3\frac{1}{2}$ inches.

"The estimated cost of reclaiming the 18,000 hectares, was 8,000,000 of florins, or £667,000 English, nearly about £13 per acre. Previously to undertaking this colossal work, the Zind Plas, of 4,000 hectares superficial, (nearly 11,500 acres) had been reclaimed at a cost of 3,000,000 of florins, or £250,000 ; not far from £22 per acre. The heights of the enclosure dike are + or — the datum line at Amsterdam, or the mean level of the sea in that port.

Embankment of the flooded part of the Amsterdam and Haarlem railway.—The bottom part consists of treble ranges of fascines, tied down by longitudinal poles 1 metre apart from centre to centre, and 0.25^c diameter; two double stakes at each end of the poles, and two ties in the intermediate distances. The interstices of the fascines and the space between the rows, are filled in with sand. The upper part, forming the encasement for the ballast, is made of three rows of treble fascines, well staked and wattled together.

"A core of sand or clay, faced with step fascines, is made

up to low-water mark. Upon this a bed of rushes, fastened down by stakes and wattles, is laid; and the upper portion of the bank is faced with fascines of a regular slope of 1 to 1."

Embankments against rivers may be divided into two kinds; namely, such as are for preventing their encroaching on the adjacent lands, and for protecting those lands and the neighbouring level country from being overflown, when the water rises above its ordinary level. It may be remarked, that where the course of a river is a straight line, or nearly so, it hardly ever makes any encroachment upon its banks, unless, perhaps, in very large rivers, when they rise above their common level, either owing to an increase in the waters, or to their being, in some degree, affected by the tides. In either case, the waves occasioned by a strong wind, where the river is wide, will moulder away the banks on that side upon which it blows, unless prevented in proper time. This may be done either by securing the bank properly with stones, or by driving a row of long piles pretty close together at a little distance from the shore, the piles being of such a length, and so driven, that their tops may be always above the highest rise of the water. It is surprising the effect that piles driven in this manner have in resisting the power of the waves in such situations.

Some years ago, when Mr. Beatson was on duty as an engineer at a fort near Portsmouth, built on a point of land much exposed to the sea, the waves made such havoc, that the walls on that side were constantly giving way, although built in the most substantial manner; and having bulwarks of large heavy stone besides, to protect the foundation: however, all would not do; those bulwarks were soon knocked to pieces, and several times the wall itself. At length it was proposed to drive a number of piles at about 40 or 50 yards from the fort. These piles were 12 or 15 inches in diameter, and driven about one diameter from each other nearly in a straight line, parallel to the wall where the waves did so much damage. They were driven into the ground with a pile-engine till perfectly firm, perhaps 8 or 9 feet deep, and about 2 feet of the top of them left above the level of high-water mark. After this was done, the wall received no farther injury, the space between the piles and the fort being always perfectly smooth, however tempestuous the waves might be without. The same simple method might, it is supposed, sometimes protect the banks of large rivers, if exposed to the waves, when other methods might fail.

But it is suggested, that the most common cause of rivers encroaching on their banks, is the resistance occasioned by a sudden bend. In flat countries, apt sometimes to be overflown, where there are any such bends or windings in the rivers, it would be of great advantage to straighten the course as much as possible; for, as every impediment or obstruction will naturally cause the water to rise higher than it otherwise would do, and as such bends have that effect, consequently, in the time of a flood the waters will overflow a greater extent of country, and to a greater depth, than if the river had a free and uninterrupted course straight forward. If the windings of the river cannot be altered, and encroachments are making on some part of the banks, it must first be considered, whether the force of the water can be driven to another place where no injury can be done. If, for example, a river is encroaching on its banks at *x*, *Figure* 13, a jetty of stone, a little way up the river, in the direction *y z*, would throw off the current towards *w*, and might totally prevent any farther encroachment. On the river Nith, in Dumfriesshire, it is stated, that a good deal has been done in this way by Mr. Millar, of Dalswinton, a gentleman of the most enterprising genius and most liberal mind, who has paid more attention, and laid out more money, in making important and useful experiments, than almost any other private individual. The course of the river, where Mr. Millar has been carrying on his operations, is said to be nearly as shown at *Figure* 14, by *r s t u*; at *t*, it was encroaching most rapidly, and seemed inclined to take a new course towards *v*, which would have destroyed some very fine land, and done a great deal of mischief in that part of the country. To prevent this, Mr. Millar made a large cut, about 400 yards in length, from *w* to *r*, and threw in a great quantity of stones quite across the river at *s*, to direct its course in a straight line from *r* to *w*. This had, in a great measure, the desired effect, by totally preventing its progress at *t*, but now it began to encroach on its banks at *u*. He at first endeavoured to prevent this by driving in, at a considerable expense, a number of piles at a little distance from the bank, and wattled them with willow branches, &c., thinking thereby to protect the bank. The piles were driven in with heavy mallets, apparently firm into the ground; they continued so for some months, till a heavy fall of rain came on, which swelled the river, undermined the piles, and carried them all away. But, indeed, it is in vain to think of piles doing any good in such a situation, unless firmly driven in by a pile-engine; for it is not possible to drive them in properly with mallets; this must have been the cause of their giving way so soon. The piles not succeeding, Mr. Millar was resolved to try another plan; several of his adjacent fields being covered with an immense quantity of stones, he ordered them to be gathered and thrown into the river, so as to form a jetty at *x*, a little way above the injured bank. Being obliged to go from home about that time, and to leave the execution of the work to some country-people, they carried out this jetty too much at right angles to the stream. It had not, therefore, the desired effect, but rather made the matter worse than before; for, if a jetty is carried out at right angles, as at *a*, in *Figure* 4, the current will be forced from *a* to the opposite side of the river at *b*, and from thence it will rebound towards *c*, more violently that it did before. But if a jetty be placed obliquely, as at *d*, it will force the current gradually towards *e*, in which position one jetty may do more good than several placed improperly at right angles. Mr. Millar was, therefore, under the necessity of making other jetties in this way, and at length had the satisfaction to find that they answered the purpose intended. Those he made laterally formed a sort of convex slope, the convexity being parallel to the current. Strong planks were also firmly set on edge among the stones, their ends pointing towards the river, so that if ever any current came so rapidly as to move any of the stones, it must move them all in a body the whole length of the plank. Perhaps this precaution was unnecessary; for although stones are thrown into a river loose in this manner, the slush, sand, &c., that come down the river will soon fill up all the cavities, and render it as firm and solid as a regular-built wall. Mr Beatson has been the more particular in this description, he says, in order to show the errors that Mr. Millar at first fell into, and the great expense they occasioned, whereas, had he been on the spot himself and got the work executed as he intended, it would have saved a great deal of unnecessary labour as well as money.

It is stated by the same writer, that the next sort of embankments against rivers, are those to prevent them overflowing their banks, and inundating large tracts of country. This may be considered as the simplest and easiest of all sorts of embanking, if judiciously executed. It is, therefore, the more inexcusable to see, in some places, extensive tracts of the richest meadows completely overflown by every flood, for want of them.

Two ordinary-sized rivers rise no more, even in the greatest flood, than five or six feet above their common level, unless when they meet with some considerable interruption or confinement in their course. But if interrupted or confined, they will rise twenty feet or more, as is the case with some parts of the river Mersey, already mentioned. If, for example, a given quantity of water is six feet deep, when running over a space twenty feet wide, it is clear, if that space were only made ten feet wide, the water would rise to twelve feet, and if it were made forty feet wide, the same quantity of water would only rise to the height of three feet. It is, therefore, of great consequence, in preventing inundations, to give the river as much width as possible, by widening every narrow place. All kinds of obstructions should also be removed, whether occasioned by windings, shoals, stones, trees, bushes, or anything else. In some cases this may even preclude the necessity of embanking; but where embanking is necessary, let the banks by all means be at a sufficient distance from each other, to contain with ease, between them, the largest contents of the river in great floods. The distance and height of the banks may easily be ascertained by measuring a section of the river when at its highest, or when the flood-mark is visible. By not attending to this, a great deal of money has been thrown away on the embankments on the river Mersey, and after all they do not effectually answer the intended purpose; a great part of the country being still overflown every time the river rises to any considerable height.

Where a sufficient distance is allowed between the embankments, their height need not exceed from four to six feet. If irremoveable obstacles are in the way, which cause the river to rise higher, the banks must be higher in proportion. In either case, however, the slope of these kinds of banks on each side may be equal to its perpendicular height, and the breadth on the top about one-third of that height, which, supposing the bank six feet high, the base would be fourteen feet, and the breadth of the top two feet, as shown at *Figure* 16, in the Plate.

The materials for making these banks should be taken as much as possible from the sides of the river, which will have the double effect of widening the river and forming the embankments; and there should be a trench on the inside (from which materials may also be got) with some sluices, as formerly directed, to drain off any water from within; also sluices to let in water from the river, if required, which would very much fertilize the meadows, if properly laid out for that purpose.

Such farms as are situated on the borders of rivers are frequently, it was observed by a late writer, liable to much injury and inconvenience from them: 1st. From part of the soil being carried away in times of flood. 2nd. From their overflowing their banks. 3rd. From their flowing back in times of flood into the channels of the rivulets and streams that conduct the water from the more elevated and distant grounds to the rivers, whereby these rivulets and streams are made also to overflow their banks.

In respect to the first, the danger of the soil being carried away in time of floods, it is increased or decreased according to circumstances, as the form of the banks, the nature of the soil, the rapidity of the river, and the quantity of water that lodges on the margins of the banks, or falls over them into the river. Where the banks of a river are perpendicular, especially if the soil be of a rich mouldering nature, the danger of part of them being carried away by floods is much greater than where they slope gently from the surface of the field to the bed of the river, as has been already fully seen.

Where that is not the case naturally, they ought to be moulded into that form by art; as when a river, in place of being confined in its progress, has a power of efflux and reflux, the damage to be apprehended is inconsiderable, compared with what is likely to happen when, being restrained within too narrow limits, it is constantly struggling for an extension of space. Where the soil is rich free mould, and the under stratum, opposite to the greatest force of the water, sand or gravel, this struggle never fails to be attended with bad consequences. If the soil and subsoil be one entire mass of clay or strong loam, and the current of the river does not press more upon one part than another, a most substantial improvement may be effected by sloping the bank, so that the declivity may be one foot in three or four from the surface of the field to the bed of the river. This some may object to, as sacrificing a certain portion of valuable land; but it should rather, it is thought, be considered as a premium paid for the insurance of the remainder, than as a total loss. If gravel, mixed with small stones, can be conveniently procured, spreading these materials on the sloping bank to the depth of eight or ten inches, and till beyond the flowings of the river, will prove a good security against farther damage; and if the bank be planted thick with any sort of willow, especially the Dutch willow, it will in a short time become an impenetrable fence, while the annual cuttings of wood will soon be equal to the heritable value of the land thus apparently sacrificed. Where no gravel can be procured, the new sloped bank should be immediately covered with well swarded turf, pressed down as hard as possible, either with the back of a spade, or with wooden mallets. If this be done in the beginning of summer, and willows planted the following autumn, the improvement will be both effectual and permanent. In case the river run with extraordinary violence against any one particular part of the bank, it may be necessary to make a fence or bulwark of stone in the front of that place; the best way of doing which, is, in place of building a wall, to drop the stones in a careless manner, but so as they may lie close together on the sloped bank, as already suggested.

This is a much more secure mode of fencing, if the bank be made with sufficient declivity, than any stone wall that ever was built for the purpose, and while it is the most secure, it is also the least expensive; but care should be taken to lay the stones all the way from the bed of the river, till considerably beyond where the river flows in common. Where the soil is of a strong adhesive nature, and the under stratum is sand or a pebbly gravel, it becomes in a much greater degree necessary to slope the banks. The water, when rushing violently along, has a powerful effect in undermining the bank; so that the soil, having nothing to support it, naturally gives way, and frequently in such quantities as to occasion very serious loss both to proprietors and tenants. In all such cases, the slope should be made much more gradual than where the soil and subsoil are of the same quality, and such as will nourish aquatic plants. The banks, having been sloped according as circumstances require, a thick coat of gravel, mixed with small stones, where such can be procured, should be laid on, so as to form a kind of natural beach, over which the river, when in flood, may have power to extend itself at pleasure. Should it be difficult or impossible to procure such materials as are proper for forming this best of all defences, strong thick sods should be placed on the surface, in the manner before directed: these, if laid on in spring, or early in summer, will have time to unite, and to become one compact body before the autumnal floods (which are those whence the greatest danger is to be expected) begin to flow. If the subsoil be of a nature unfavour-

able to the growth of willows, such sods as are full of the roots of rushes should be made choice of in preference to all others; as, where these plants thrive and spread over the surface, it becomes in a great degree impenetrable by water, even in great floods, and when the river runs with considererable violence and rapidity.

The directions above given will, it is supposed, be found more or less practicable and useful according as the river on ordinary occasions runs with greater or less rapidity. In level, or nearly level districts, all that is necessary is to secure full scope for the rivers to overflow their usual bounds without interruption; when that is secured by either of the methods before mentioned, floods, unless very violent, seldom do any material damage to the banks of rivers in such situations. It becomes in many cases extremely difficult to fence rapid running rivers in such a manner as to prevent part of the banks from being carried away by inundation. Sloping the banks would be attended with no good consequences. Even strong bulwarks made of stone are often swept away by the overpowering flood. A method has, however, been suggested, of fencing the sides of a rapid running river, which has been practised with success, after several other attempts had failed: it is by means of a sort of large baskets, provincially termed *creels*, formed of hazel, willow, &c., into a kind of open network, which being placed along the bottom of the banks, are filled with stones. This is a very simple, and by no means an expensive expedient; and as these baskets may be made to contain two or three tons of stone, it can only be on few occasions, and in very particular situations, that a basket, containing such a weight, can be displaced or carried away. Such a mode of fencing as this, it is imagined, would prove effectual in many parts of Scotland and Wales, where the rivers run with uncommon rapidity. Owing to inattention, or rather to not being aware of the consequences, much damage is often done to the banks of rivers in level districts, especially if the banks be perpendicular, and of a considerable height, by allowing the land-floods to fall over them into the river. As the water from the furrows approaches the bank, it is frequently stopped in the furrow of the head ridge, which becomes for a time a kind of reservoir; the consequence of which is, that a considerable proportion of water sinks and filters through the earth, which being thus softened and swelled, is more easily undermined and carried off by the river. Sometimes little cuts or openings are made for the furrows across the head ridge, for the purpose of conducting the rain-water into the river; here, again, the consequences are equally bad. Whoever will examine the bank of a river where this mode of management is adopted, and it is very common, will observe, that at every one of these cuts or openings a little creek is formed, in consequence of the bank having been more softened, and by that means having become a more easy prey to the river when in flood. To prevent these evils, it is necessary, besides sloping the banks, to devote a part of the lands adjoining, to the breadth of 20 or 30 yards, for instance, either to pasturage or the growth of trees, and to form a drain at a proper distance from, and parallel to the bank, for the purpose of collecting and carrying off the water from the furrows. Were this done, and were the water from this drain conducted into the river by conduits formed a little above its ordinary level, much land, which is annually lost by neglecting this simple precaution, would be saved, and preserved in a proper state.

In the second case, it is evident that injuries, although of another nature, are often sustained by farmers, from rivers overflowing their banks. Sometimes the farmer is prevented from sowing his field; at other times the crops of grain and grass are greatly injured, by being covered for a considerable time with water; and at others again, the whole produce of the year, the hay and corn crops, are swept away. To prevent evils so complicated, and so serious in their nature, is certainly the business of every man, who, from the situation of his farm, has reason to apprehend, that, without using proper precautions, he may be subjected to such visitations. These damages can only happen in level tracts, where the banks of the rivers are low, and where the course is not of sufficient breadth to contain the water in time of flood. Some people, although very improperly, raise mounds of earth close to the top of the bank, and of a height exceeding that to which the river can be expected at any time to rise. These mounds, from being placed so near the river, are unable to resist the pressure of the water, and by giving way frequently admit a current into the fields, which proves much more injurious in its course than if no mound whatever had been erected. Were a mound of earth formed on the side of the drain, proposed to be made for carrying off the land water, and were that mound well sloped on the side towards the river, it would be the most secure and effectual guard against rivers doing injury to the adjoining lands, of any that could be adopted. By these mounds being placed at a distance from the river, the force of the stream would be much lessened, and the natural boundaries of the river greatly enlarged; as, in proportion as the mounds are removed from the centre of the current of the river, in like proportion will they become more secure, as being less liable to violent pressure. The propriety of erecting these mounds at a proper distance must, therefore, be sufficiently evident; as, when mounds are erected near the top of the bank, which can only be owing to ill-judged parsimony, they form as it were a part of the bank, and are liable to be undermined and swept away. Whereas, when they are placed at the distance of 20, 30, or 40 yards, they serve rather as a boundary to confine the overflowing waters which glide along the bottom, than as a barrier to prevent the encroachments of an impetuous river during the time of floods.

In regard to the third case, it is observed, that farmers who possess lands in low situations often sustain damage from rivers, in time of flood, by their flowing back into the channels of the rivulets and streams that conduct the water from the more distant and elevated grounds to the rivers, whereby these rivulets and streams are made also to overflow their banks.

The only precaution that can be adopted, in such a case, or at least the one which appears to have the greatest probability of answering the purpose, is to erect mounds at a distance from the banks, and of a size proportioned to the quantity of water, which, from the cause now mentioned, may be supposed at any time to stagnate in these channels. This may be done at a very trifling expense either in money or land. If the proprietors do not choose to ornament the country and improve their own estates, by planting trees on the borders of the rivulets and streams, the farmers may so construct these mounds, as that they may become fences to their arable fields, while that portion of the farm, necessarily and properly cut off for the protection of the remainder, may be devoted to pasturage.

Several different embankments of a successful kind have been effected in the northern parts of the kingdom. An important work of this nature was some years since executed on the estate of Lord Galloway, situated on the mouth of the river Cree, near Cree-town, by his lordship's tenant, Mr. Thomas Hannay, who states, in the third volume of the "Farmer's Magazine," that at the time he entered on the farm, upwards of 100 Scottish statute acres were regularly

flooded by the highest spring-tides, excepting about three months in summer, when the tides were lower. They were seldom, however, covered above the depth of one or two feet, and never above four or five. Eighty acres of the above consisted of a rich sea marsh, or *ings*, as they call them there, almost a true level, excepting where hollows were formed by the egress and regress of the tides, and the passage of fresh water from the higher grounds; and about 4 or 5 acres, which were about 16 inches lower, being a younger marsh, and nothing but what they call ink-grass growing upon it; other grasses, such as clover, rib-grass, &c., grew on the rest of the marsh, forming a very beautiful close cover in the summer. The other 20 acres were on an average about 18 inches higher; consequently the sea did not cover them so often. It had formerly been ploughed, but not for about 20 years past. Last time it was in corn, it was flooded immediately after being sown, which rendered the crop almost entirely useless, and deterred former tenants from ploughing it again. Mr. Hannay began to bank this field in the autumn of the year 1798, by making a dike along the side opposite to the river, in a direct line facing the east. This dike was made, at an average, about $3\frac{1}{2}$ feet high, and 6 feet broad at bottom, and 20 inches at top, built after the same manner with that mentioned below He enclosed, along with the said fields, he says, 4 acres of the marsh adjoining, by making a dike 5 feet high, and 5 feet in bottom, almost wholly of solid feals or sods, with a very little stuff, properly beat, in the heart of it, which makes an excellent fence, and promises to be a very durable one. This dike, together with two small drains, one on each side of it, about two feet deep, cost 3d. per yard. The division-dikes of the whole marsh, which now, divided into 4 parts, are all built after the same manner, only that there is no loose stuff in the heart of some of them, but all of solid feal, jointed like bricks, as may be seen at *Figure* 17, which represents an end view, or section of it. This dike, meant as a permanent fence, answered as a temporary bank, and enabled him to plough that field in spring, 1799, although the bank round the whole marsh was not finished till the winter following. He sowed oats on this field, and, considering the badness of the season, had a very good crop; particularly so on that part which had not been ploughed formerly. On farther consideration, he altered the plan of the bank round the marsh, (which extends in a circular direction facing the north) by making it, at an average, about four feet and a half high, and allowing about two feet in the base for one in height, as at *Figure* 18, where *a b c* represents an end view, or section of it, every small span representing the section of a feal or sod; *a b* shows the inside of the bank, with the green side of the feal down; *b c* the base; *a c* the side next the water, with the green side of the feal out, (which adds greatly both to the strength and beauty of the bank;) and *d* the heart of the dike, made up with stuff properly compressed with a rammer. The stuff was taken from a ditch, in the inside of the bank, leaving a casement of a foot, which ought to have been three at least; and, where the ground is of a sandy nature, more; as the fresh water, running in the inside, was likely to undermine the bank, had he not prevented it, by cutting a new drain, and filling the old one with the stuff cast from it. The only creek worth noticing, through which the bank passed, was about 40 feet wide and 9 feet deep, in the bottom of which a wooden pipe, with a stopper, was laid through th[illegible]k.

There are [illegible]ut 50 acres of the same kind of marsh-land adjoin[illegible] and also about 100 acres on the other side of the [illegible]nked in, all nearly in the same manner as represent[illegible]e figure. The bank on a farm on the side of the river opposite to his, was made almost a complete wreck, by an extraordinary tide, owing to its lying quite exposed to the south-west winds, which always send up the highest tides; but on his side, though suffering some injury from the same high tide, he was not affected by those winds, as they blew right over the bank. In his opinion, the bank on the other side of the river, in order to be durable, would require to be 30 feet broad, and 8 feet high, covered with feals, with the green side out; and that no stuff should be lifted within 6 or 7 feet of it, the ground being of a sandy nature. It might be made after the form shown at *Figure* 19. The whole of this turned out most excellent land, and continues to produce to this day some of the finest crops in that part of the country.

Another improvement of the same nature was accomplished on what in Scotland is termed *carse land*, on the farm of Netherton of Grange, belonging to James Peterkin, Esq., by Mr. John Hoyes, his tenant. The work was undertaken under an agreement with the proprietor, to allow one year's rent, of £195 sterling, with the farther allowance of ameliorating the farm-houses to the extent of £150 more. The method adopted for carrying on the operations was this:—After looking over the carse, and marking out the line or dike, the length of which is 1,400 yards, mostly in a right line, except an angle at the distance of 300 yards from the west end, and a segment of a circle at about 250 from the south-east end, it was resolved to make the embankment 6 feet high in the highest part of the ground, and to allow 2 feet of breadth in the bottom of every foot in height, as seen by the draught of the mould at *Figure* 20. After taking the level of the carse, it was found that where the ground was low, and a good deal of it broken by runs of the sea and outlets for the water, the dike would require to be 8 and 10 feet high, to have it on a level at the top; so that the average would be 9 feet high. The embankment was built in the following manner: It was begun on the highest ground, near the west end, and two moulds set up at the distance of 70 or 80 yards; the height, 6 feet, by 12 broad in the base; the slope on the outside 6 feet, on the inside 4 feet, and the breadth at the top 2 feet; the sides made up with feal from the broken ground on the outside of the dike, which were laid with the grass-side down, two feal deep on each side of the dike; the outside feal of the first course with the ends out and in, and the other running along; the next course, the outside feal running along, and the outside out and in, and so on alternately, each course consisting of a head and runner; the body of the dike being made up of the carse ground from which the feal had been cut, and packed down by men with beaters. When this was brought to the height of 4 or 5 feet, another piece was begun, leaving an intermediate space, where there were any water-runs, for the egress of the tide: this was found necessary, to draw off the water from the low parts of the carse, which would have been filled up in spring tides; and, by coming in at the end and over the high ground, would have been prevented from getting out by the dike, if it had not been done in that way; so that the embankment was all in detached pieces, till it was brought near the height. These intermediate spaces were then filled up, between the fall of one and rise of next spring-tide, after laying down wooden pipes with stoppers in the dike, to carry off the sink-water. In carrying on the work, they had in some places to cross over lakes and runs made by the tides, which required vast quantities of materials, the dike being in some places upwards of 10 feet high, and 22 broad in the base; the greatest part of the dike being 16 to 18 feet broad. There was one lake of 150 feet in length, and 50 feet in breadth, filled up with earth, clay, and sand, to the height of 5 feet; on which the

dike was then built. This forms a mound, on the outside of the dike, of 15 or 16 feet broad; and through this there are pipes laid, to carry off the sink-water. A stream of water was also turned by the west end of the farm, by cutting a canal, which conveyed the water through the embankment there, by means of an outlet built of stone, with a sluice on the inside, raised to the level of the running water, and a folding door on the outside, to be shut by the spring-tides. At this place, a road, that formerly led to Findhorn at low water through the carse, is carried over the top of the dike, by making a mound of earth at each side, with a gradual approach and descent.

In *Figure* 20, *a*, is the breadth of the dike at the top, when finished; *b*, the breadth of dike at the bottom, being twelve feet, when it is six feet high; *c*, the breadth when eight feet high; *d*, the breadth when ten feet high; *f*, the slope on the sea-side of the dike, which is always equal to half of the breadth of the bottom: the inside slope, and breadth of the dike at the top, is equal to the other half; and *e* is the plumb-rule in a frame, made to apply to the mould or dike: the intention of it was, to find if the dike was kept on the proper slope, where a line could not be applied from one mould to another, as in a round or turn, or when the moulds were obliged to be taken down; but this one only answered for the sea-side, another being used for the inside, to fit its slope." *Figure* 21, is a scale of the mould, one-eighth of an inch to a foot.

A curious, useful, and highly ingenious method of embanking, and preventing the waters of the tides from soaking through the porous banks, made in the fen-lands, and low marshy grounds, was described by Mr. John Smith, in the fourth volume of "*Communications to the Board of Agriculture*," who begins by "concisely observing, that the great land of the fens is divided into three large levels; and that each of these levels is subdivided into numerous districts by banks: but as these banks are made of fen-moor, and other light materials, whenever the rivers are swelled with water, or any other district is deluged either by rain, a breach of banks, or any other cause, the waters speedily pass through these light, moory, porous banks, and drown all the circumjacent districts. The fens have thus sometimes sustained £20,000 or £30,000 damages by a breach of the banks, though these accidents seldom happen in the same district twice in twenty years. The water, however, soaks through all fen-banks every year, in every district; and when the water-mills have lifted the waters up out of the fens into the rivers in a windy day, a great part of the water soaks back through the porous banks, in the night, upon the same land again." And he adds, that "this water that soaks through the bank drowns the wheat in the winter, washes the manure into the dikes, destroys the best natural and artificial grasses, and prevents the fens from being sown till too late in the season. This stagnant water lying on the surface, causes also fen-agues, &c. Thus, says he, the waters that have soaked through the porous fen-banks have done the fertile fens more real injury than all the other floods that have ever come upon them."

Having been much concerned in fen-banking from his youth, he had some time since devised the plan which he now finds to answer so well; but found it difficult to prevail with any gentleman, who had a proper extent of this sort of land, to give it a fair trial. However, during the last autumn, he prevailed with a person in the parish where he lives to try it, which showed it to be equal to his highest expectations.

The improved method of embanking proposed by this gentleman, consists chiefly in this: that "a gutter is cut eighteen inches wide, through the old bank down to the clay (the fen substratum being generally clay;) the gutter is made near the centre, but a little on the land-side of the centre of the old bank. This gutter is afterwards filled up in a very solid manner with tempered clay; and to make the clay resist the water, a man in boots always treads the clay as the gutter is filled up. As the fen-moor lies on clay, the whole expense of this cheap, improved, and durable mode of waterproof banking costs in the fens only sixpence per yard. This plan was tried on a convenient farm, and a hundred acres of wheat were sown on the land. The wheat and grass lands on this farm were all dry, whilst the fens around were covered with water. This practice is, after all, nothing more than making a *puddle-bank*, well known to all engineers, or those engaged in forming canals.

The term embankment in canal-making is applied to any large mound of earth, either for confining the water of the canal or reservoir, or for carrying the former across a valley or low piece of ground. The method of constructing such embankments is nearly the same as in those for railways, except that in the former the sides have puddle-trenches formed near the canal, to prevent leakage.

The embankments on some of the great lines of railway in this country are of immense magnitude, on the London and Birmingham railway, for instance, the total of embankments amounted to about 11 millions of cubic yards. The following extracts from specifications for works of this kind will show the usual mode of construction.

"The whole of the embankment in this contract shall have slopes of two to one (that is to say) where the base of the slope is two feet, its height shall be one foot only, and they shall be thirty-three feet wide at the level of the red line in the section, neither more nor less.

"Each of the embankments shall be uniformly carried forward as nearly as the finished heights and width as the due allowance for shrinking of materials will admit of, and this allowance shall not exceed or fall short of the quantity deemed necessary by the engineer. In all cases, this must be carefully and strictly attended to, in order to avoid the necessity of making any subsequent addition, either to heights, or the width of the embankment, to bring them to their proper level and dimensions.

"The surface of the embankment shall be kept in such form or be intersected by such drains, as will always prevent the formation of pools of water upon them, and insure the embankment being kept as dry as possible.

"Whenever the material, teemed over the end of the embankment, shall not form the proper slope, it shall be carefully trimmed to its required form; and this operation must proceed at the same time with the end of the embankment, so as to obviate the necessity of any future addition of material to the sides of the embankment.

"As the embankments advance, and become consolidated, the slopes shall be carefully trimmed into planes having the proper slope, and be neatly covered with a uniform substance of turf, of not less than eight inches in thickness, and laid with the green sward outwards; the turf must be taken from the ground to be occupied by the base of the embankment, and cut square, so as to be laid on the slopes in the form of flags; and where the land is arable, the slopes of the embankment shall be covered with soil. It must be uniformly laid on, of the thickness of six inches, and sown with rye-grass and clover-seed, as soon as the proper season will admit of its being done, not less than one pound and a half of clover-seed, and one pound and a ha[illegible]-grass seed, to be sown to each acre.

"When the material, brought to the [illegible]ent, consists of large lumps, they shall be broken int[illegible]s of not more than six inches in diameter."

Expense of forming embankments.—This must obviously be very different in different situations and circumstances, according to materials and the price of labour, but though in general pretty considerable, it is seldom so high as is commonly supposed. It is probable, that in cheap districts, and where the materials are plentiful, the expense of forming an earth-bank, covered with sand or gravel, such as that shown at *Figure* 1, could not be less than from fourpence or sixpence, to tenpence or a shilling, the cubic yard. And such as have more steep and bold slopes, as from thirty-five to forty degrees, and are formed with pavement on the surfaces, cannot cost less than from ninepence to one shilling the cubic yard. One made on the plan of that shown at *Fignre* 6, could not be constructed for less than from twelve or fifteen to thirty pounds for every thirty-two yards. And one constructed of brushwood, in the same method, for soft ground, which will not admit of a wall, would not be lower than from sixpence or eightpence, to six or seven shillings for each foot forward in a lineal manner. In many situations, the ezpenses would, however, in all sorts of embankments, stand a great deal higher than these.

In some districts, embankments are formed by the rod and the floor, the former being from four to five pounds, and the latter about four shillings and sixpence, the workmen finding all sorts of necessary things for the business.

EMBATTLED BUILDING, a building with embrasures in the parapet, resembling a castle or fortified place.

EMBATTLED LINE, a straight line bent into right angles, so that if there be two sets of parts, the parts of each set may be in the same straight line, and parallel to the parts of the other.

EMBATTLED ARONADE, is partly the same as the EMBATTLED LINE, the difference consisting of a semi-circle raised in the middle of each part which forms the continuation of one of the straight lines, the semi-circle presenting its convexity towards the parts which form the other straight line.

EMBATTLED BATTLED LINE, a straight line bent into right angles, so that if there be three sets of parts, one set may be parallel to those of the other two.

EMBLEMATA, a kind of inlaid or mosaic work, used by the Romans in flooring, panelling, &c.

EMBOSSING, the act of forming work in relievo, whether it be cast, moulded, or cut with a chisel.

EMBOSSING, in architecture, that kind of sculpture in which the figure stands in relief beyond the plane, or other surface from which it seems to rise. The several kinds of sculpture formed by embossing are, *low relief*, *mean relief*, and *high relief.*

EMBRASURE, an enlargement or splay of the aperture of a door or window, generally withinside the wall, for the admission of a greater quantity of light; when the wall is very thick, an enlargement is also made on the outside of the wall.

EMBRASURE, is also applied to the apertures of an embattled parapet. It is another term for the crenelles, or intervals between the merlons.

EMBROIDERY, the enrichment of woven fabrics by the introduction of devices in needlework. Embroidery was a kind of work very usually employed in ecclesiastical hangings, vestments, and the like, and, in such cases, is of the most gorgeous and elaborate description.

EMPLECTON, a kind of walling, used by the Greeks, and the Roman villagers, consisting of rubble masonry, with facings of wrought stones laid in regular courses. *See* WALLS.

ENAMELLING, a method employed to enrich metal-work by the introduction of colour, much used in the works of the middle ages. Specimens of enamel of an early date are to be seen on the envelopes of Egyptian mummies, also in Greek and Roman work, &c.

ENCARPUS, sculptures of fruit or flowers, such as those employed in the decoration of friezes.

ENCAUSTIC, a term applied to paintings, in which the colours are fixed by means of heat. *Encaustic tiles*, are those in which coloured devices are introduced, the colours being burnt in during the process of manufacture.

ENCHASING, that mode of decorating metal-work in which the devices are represented in low relief.

ENDECAGON. *See* HENDECAGON.

END-IRONS, otherwise *and-irons*, standards, usually of metal, and of various forms, used in fireplaces previous to the employment of coal for fuel, to support the logs of wood.

ENDS OF A STONE, the two parallel sides, which form the vertical joints.

ENGAGED COLUMN. *See* COLUMN.

ENGINE, *Pile*. *See* PILE ENGINE.

ENGLISH ARCHITECTURE, a term applied by some to the styles of Gothic architecture as developed in England. *See* GOTHIC and DOMESTIC ARCHITECTURE.

ENGLISH-BOND, in bricklaying, a disposition of bricks, wherein a course of headers succeeds a course of stretchers alternately. In the north, bricklayers frequently run three or five courses of stretchers to one of headers.

ENGLISH OAK, oak timber of the native produce of England. It is much used in the country for rustic buildings, and is particularly useful in the truss-posts of roofs, as being less liable to compression, and possessing a greater degree of tension, than fir.

ENNEAGON, a figure of nine sides and angles.

ENSEMBLE, (a French word, signifying *together*, or *one with another*, formed of the Latin *in* and *simul*,) the work or composition of a building, considered as a whole, and not in parts.

ENTABLATURE, (French, from the Latin *tabulatum*, a stage, or story,) that part of an order which is supported by the column or columns, and forms the covering or shelter to the edifice. It consists of three principal divisions, viz., the architrave, which rests upon the capitals of the columns; the frieze immediately above it; and the cornice at the summit. These divisions, according to Vitruvius, represent the principal timbers used in the roof of the timber-building, which he supposes to have been the origin and type of erections in stone. This subject has been already referred to under the title DORIC ARCHITECTURE. The entablature either finishes the whole edifice, or so much as has the order applied to it; and in strictness ought to terminate either in a level cornice, or in a pediment formed of two equally inclined cornices. This rule, however, was not always adhered to by the Romans: for in many of their buildings, we find the ordonnance crowned with an attic or blocking course. The edifices of Balbec and Palmyra were often finished in this manner; as were even some of the Grecian structures, after Greece had become a Roman province.

The general height of the entablature is equal to two diameters of the column; though some authors make the Doric entablature one-third of the height of the column; and the entablature of the Ionic one-fourth, and that of the Corinthian or Composite, each one-fifth of the respective columns. Vignola makes the entablature one-quarter of the height of the column, in each of the orders; but the former proportion of twice the breadth of the base agrees much better with the ancient Grecian examples than the other two. It must be recollected, that in ancient examples of the same Order, the height of the entablature is in some instances more, in others less, than two diameters. In the temple of Minerva, at Athens,

which is one of the most chaste of the Grecian Dorics, the entablature is almost precisely two diameters of the column. In the Corinthian or Composite, where the column is ten diameters in height, the proportion found in some ancient examples of later date, one-fifth of the said height, is exactly two diameters of the foot of the shaft.

To find the proportions of the different parts of the entablature, divide the total height into ten parts, of which give three to the architrave, three to the frieze, and the remaining four to the cornice. This will stand as a general rule, but in the Doric order the proportions are somewhat different, the architrave containing two-eighths, and the frieze and cornice three-eighths each.

The entablature is also called *trabeation;* and by Vitruvius and Vignola, *ornament.*

ENTABLATURE, or ENTABLEMENT, is sometimes used for the last row of stones on the top of the wall of a building, whereon the covering rests. As this is frequently made to project beyond the naked of the wall, to carry off the rain, some authors call it, in Latin, *stillicidium*, or *drip;* but such an entablature does not stand out far enough, but permits the water to fall on the foot of the wall.

ENTAIL, a term used in the middle ages to designate all kinds of sculpture and carved decoration, but more especially applied to the more elaborate enrichment.

ENTASIS, the swell observable in the shafts of Grecian columns, and more particularly in those of the Doric order. Amongst the modern Italian architects, the practice has been carried to an absurd excess. Several methods of describing the curve will be found under the article COLUMN.

ENTER, (from the French *entrer*, to go in,) in carpentry and joinery, to insert the end of a tenon in the mouth or beginning of a mortise, previous to its being driven home to the shoulder.

ENTRESOLE, (French,) an intermediate story; a low floor introduced between two principal ones. *See* MEZZANINE.

ENTRY, (from the French *entrée*, a passage,) a door, gate, passage, &c., for admission into the interior of an enclosure, house, or apartment.

ENVELOPE, (French,) the covering of a portion of the surface of a solid, by means of a thin pliable substance, which comes in contact in all points or parts with such surface.

To develope the surface of a solid, is to find the envelopes that will cover its different parts.

A few examples of the developement of surfaces will be here given, and for further information we refer the reader to the article SOFFIT.

Problem I.—*To develope that portion of the curved surface of a cylindroid, which is contained between two parallel planes, and another plane passing through the axis at right angles with the parallel planes.*

Plate I. *Figure* 1.—Let M N L C be the plane passing through the axis, terminated at M C and N L by the parallel planes, and by the surface to be developed, at M N and C L; the four lines M C, C L, L N, N M, forming a parallelogram, M C, L N. Draw C A C_8 at a right angle with C L, and produce N M to A; then A C is one of the axes of the elliptic section, at right angles to the axis of the cylindroid. On A C describe the semi-ellipsis A B C, having its other semi-axis equal to that of the cylindroid; divide the curve A B C into any number of equal parts, say eight, and extend them from A to C_8, which coincides with the termination of the eighth part, marking the respective points as 1, 2, &c., at *e*, *g*, &c. Through the points of division, 1, 2, 3, &c., in the arc, draw the straight lines 1 E F I, 2 G H K, parallel to A M: also, from the points *e*, *g*, &c., draw lines *e f i*, *g h k*, &c., parallel to A. M. Transfer the distances, E F, G H, &c., to *e f*, *g h*, &c.; through the points M, *f*, *h*, &c., to C_8 draw a curve; and C_8 M N *l* will be the envelope required.

Problem II.—*To develope the surface of a cylinder contained between two other concentric cylindric surfaces and a plane, in such a manner that the axes of the two cylindric surfaces may cut the axis of the first cylinder at right angles, and that the plane may pass along the axis of the first cylinder, and cut the axes of the two cylinders at right angles.*

Figure 2.—Let A C L N be the plane terminated by the arcs A C and N L, which are the intersections of the concentric cylindric surfaces, and by the parallel straight lines A N and C L, which are formed by the curved surface of the cylinder intersecting the plane.

Proceed in every respect as in *Figure* 1, and the envelope will be obtained; the referring letters being alike in both *Figures.*

Problem III.—*To develope that portion of the surface of a cone contained between two parallel planes and a third plane, so that the axes of the code may be cut at right angles by the parallel planes, and that the third plane may pass along the axis of the cone.*

Figure 3.—Let A E F C be the plane passing along the axis, terminated at A C and E F by the parallel planes, and at A E and C F by the curved surface of the cone. A B C is a section of the cone, perpendicular to the axis. Produce A E and C F to meet in D; and with the radii D E and D A describe the arcs E G and A C; extend the semi-circumference of A B C on the arc A C, from A to C, and draw C G D; and A C G E will be the envelope required.

Problem IV.—*To develope that portion of the surface of a cone contained between two concentric cylindric surfaces and a plane passing along the axis, so that the plane may cut the common axis of the cylindric surfaces at right angles.*

Figure 4.—Let A I K C be the portion of the plane passing along the axis, and the arcs A C and I K the intersections of the cylindric surfaces; the straight lines A I and C K, the intersections of the conic surface. A B C is a section upon the chord A C. From D, with the radius D A, describe the arc A M; divide the semi-circumference A B C into any number of equal parts, and extend them upon the arc A M, from A to M, at the points 1, 2, 3, &c. to M: draw 1 D, 2 D, 3 D, &c. to M D included; also, through the points 1, 2, 3, in the arc A B C, draw lines perpendicular to A C, cutting it in as many points: from these points, draw lines to D, cutting both the concave and convex curves; from the points so cut, draw lines parallel to A C, cutting A D; then from the points of intersection, made by the parallels drawn from one of the curves, describe the several arcs drawn from the point D, to cut the respective straight lines. Proceed in the same manner with the other curve, and through the points so obtained, draw the two curves; and A M L I will form the envelope required. But to show more particularly how the successive points in the curve of the envelope are found, we shall only describe a single point, and the remaining points will be obtained in the same manner; thus, to find the point H in the envelope, draw 2 E perpendicular to A C, cutting it at E; draw E D, cutting the curve A C at F; draw F G parallel to A C, cutting A D at G; from the centre D, describe the arc G H, cutting 2 D at H, which is a point in the curve, as before stated; but by drawing the several systems of perpendicular lines, of lines going to a centre, and parallel lines, at once, much time will be saved in the operation.

Problem V.—*To develope the surface of a cuneoid contained between two parallel planes, and a plane passing along the axis of the cuneoid, so that the parallel planes may be perpendicular to the plane passing along the axis, the section of one of the parallel planes being given.*

Figure 5.—Let A B C D be the plane passing along the axis, terminated by the straight lines A D and B C, which are the intersections of the parallel planes, and by the straight lines A B and C D, which are the intersections of the cuneoidal surface. Let the section B E C, standing upon B C, be a semicircle, and, consequently, the section A F D formed by the other parallel plane, will be a semi-ellipsis of the same altitude.

Produce A B and D C to meet in G, divide the arc B E, which is the half of the semi-circumference, into any number of equal parts, say four, from the points of division, draw the perpendiculars 1 H, 2 I, 3 K, E L, cutting B C at H, I, K, L: draw G P perpendicular to A G; on G P make G *m*, G *n*, G *o*, and G P respectively equal to H 1, I 2, K 3, and L E; from the points *m*, *n*, *o*, P, as centres, with the respective distances G H, G I, G K, and G L, describe the arcs *h r*, *i t*, *k v*, and *l x*; extend the arc B 1, or 1, 2, which is the eighth part of the semi-circumference, from B to *h*, from *h* to *i*, from *i* to *k*, and from *k* to *l*; then drawing the curve B *h i k l*, will give the half of the envelope, which will coincide with the arc H E, when the semi-circle H E C is turned perpendicular to the plane, A B C D, upon its base B C: and since *l* P is the middle line, the other half, or counter part, will easily be found. To develope the elliptic edge, join *m h*, *n i*, *o k*, and P *l*, and produce them to *u*, *s*, *t*, *f*: transfer H U, I S, K T, to *h u*, *i s*, *k t*, *l f*, and through the points A, *u*, *s*, *t*, *f*, draw a curve A *u s t f*, which will be the envelope of the arc A F, the half of the semi-ellipsis A F D; then the counter part being found, will complete the envelope A B C *d* of the curved surface, standing over A B C *d*.

Problem VI.—*To develope that portion of the surface of a cuneoid terminated on two sides by a plane passing through the axis, and by two concentric cylindric surfaces whose axis is perpendicular to the plane given; given that portion of the plane terminated by the curved surface of the cuneoid, and by the intersections of the two cylindric surfaces; also, the semicircular section of the cuneoid.*

Figure 6.—Let A E and B G be the intersections of the cuneoidal surface, and the arcs A E B and E F G the intersections of the concentric cylindric surfaces.

Let D C be the intersection of the section, which is a semicircle, then find the envelope for the semi-circumference, as in the last problem for parallel planes; then the lengths of the intermediate lines contained between the base of the circular section, and the intersections of the cylindric surfaces, being transferred upon the corresponding lines from the semicircular envelope, will form the covering of the cuneoidal surface, as defined.

The reader will observe, that the two last constructions in *Problems* V. and VI., are only approximations near to truth; it is, we believe, impossible to find the true envelope by means of straight lines, or perhaps even to extend the true cuneoidal surface on a plane at any event, any more than that of a sphere, which can only be represented by means of projections. The only surfaces which can be extended on a plane, are those to which a straight edge will everywhere apply through a certain point, or in parallel directions to a given line; of this description are the surfaces of planes, cones, and cylinders: a straight line will apply to all parts of the surface of a cone through the vertex, and to all parts of a plane through any given point, and to all parts of the surface of a cylinder parallel to the axis.

The envelopes of all solids, to which a tangent plane to its surface parallel to the given plane will apply, have the same curvature or straight line at the edge, where the plane becomes a tangent, as the corresponding part of the edge of the given plane.

In describing the envelopes of solids, the whole or a portion of the section passing through the axis, is always supposed to be given, as also a section of the solid, making a given angle with the said plane, and the intersection in a given position.

If only a portion of the section passing along the axis be given, it is always supposed to be terminated by the same surfaces, which also terminate the surface to be covered.

The following is a more general method of finding the envelope of a solid by means of points.

In this description it will only be necessary to have the seats of three points given on the base, and the heights of the points on the cylindric surface from their seats. Let A B C (*Plate* II. *Figures* 1, 2, 3) be the part of the base of the cylinder, and A, B, C the seats of the three points; join A C: draw C E and A D perpendicular to A C; make A D equal to the height of the point above A, C E equal to the height of the point above C, and C F equal to the height of the point above the seat B; join E D; draw F G parallel to C A, and G H parallel to C E, cutting A C at H; and join H B; produce A C to I; divide the curve A B C into any number of equal parts; and extend those parts upon C I; through the points of division in the curve, A B C, draw lines parallel to B H, intersecting B C; from the points of intersection in A C draw lines parallel to G H, to meet D E; from the points of intersection draw lines parallel to A C; and from the divisions in C I draw lines parallel to C E, so as to intersect the other parallels last drawn; through the points thus found, draw the curve C I K E C, and it will be the envelope required.

Figure 1, is the case where the rectangular plane makes a right angle with the elliptic section:

Figure 2, that where the angle made by the rectangular plane and the elliptic section is acute:

Figure 3, where the angle formed by these two planes is obtuse.

In *Figures* 2 and 3, D M E is the orthographical projection of the curve; with which the curve, E K, of the envelope would coincide. This is found by drawing parallels to G H through the points of division in the curve A B C, to meet the parallels of A C, as shown by the dotted lines.

EPHESUS, an ancient city of Ionia, formerly the metropolis of Asia Minor, now in ruins. The celebrated temple of Diana, in this city, was deemed one of the seven wonders of the world. In the time of Pococke, the remains of this renowned metropolis consisted of the temple of Diana; a circus; a gymnasium; a large theatre, and two of smaller dimensions; an odeum, or music theatre; a building, called the *Athenæum;* another, called the *Hypelæum*, of which there are yet considerable remains; with some vestiges of an aqueduct, and other fragments. A great part of the ancient walls are still entire, but in some parts the foundations only remain, from which it appears they were ten feet thick. Most of these vestiges are represented in Pococke's *Travels in the East.* The situation of this city was very favourable to the procuring of materials, being in the vicinity of Mount Lepre, which consisted of rocks of stone and marble, whose elevated situation afforded the means of an easy transit of the stones or blocks for building, to the site of the intended fabric.

EPICYCLOID, in geometry, a curve generated by the revolution of a point in the circumference of a circle, while it is moved round the circumference of another quiescent

circle in the same plane, so that in each circle, the distance between the point of contact at the commencement of the motion, and the point of contact at any instant while in motion, is equal one to the other. Hence if the circumferences are equal, all parts of the circumference of the moving circle will have been in contact with all the parts of the circumference of the quiescent circle.

If the generating circle proceed along the convexity of the periphery, it is called *an upper*, or *exterior epicycloid:* if along the concavity, *a lower*, or *interior epicycloid.*

The part of the quiescent circle which the generating circle moves along, is called *the base.*

The length of any part of the curve, which any given point in the revolving circle has described from the time of its first being in contact with the quiescent circle, is, to double the versed sine of half the arc, as the sum of the diameters of the circles, to the semi-diameter of the quiescent circle; provided the circumference of the moving circle be carried along the convex side of the quiescent circle; but if upon the concave side, as the difference of the diameters to the said semi-diameter.

Dr. Halley gives us a general proposition for the measuring of all cycloids and epicycloids: thus, the area of a cycloid or epicycloid, either primary, contracted, or prolate, is to the area of the generating circle, and also to the areas of the parts generated in these curves, to the areas of the analogous segments of the circle, as the sum of double the velocity of the centre, and the velocity of the circular motion, to the velocity of the circular motion. The demonstration hereof, *see Phil. Trans.* No. 218.

The areas of epicycloids may be determined by the following proportion: As the radius of the circle of the base is to three times that of the radius, together with twice that of the generating circle, so is the circular segment to the epicycloidal sector, or the whole generating circle to the whole area of the epicycloid.

As to the tangents, it is known from the time of Descartes, that a line drawn from any point to that of the base, which touches the circle, whilst this point is described, is perpendicular to the curve, and consequently to the tangent.

Maupertius, discussing this subject, conceived a polygon to revolve upon another, the sides of which are respectively equal; one of the angles described a curve, the periphery of which is formed of arcs of circles, and the area is composed of circular sectors, and right-lined triangles. He determined the proportion of the area, and of the periphery of this figure to those of the generating polygon. He also supposed those polygons to become circles, the figure described to become an epicycloid, and the above-mentioned proportion, modified agreeably to this supposition, gave him the area and periphery of the epicycloid. *Mem. de l'Acad.* 1727.

It does not appear that any writer published an account of epicycloids, before the celebrated Sir Isaac Newton, who, in the first book of his *Principia*, proposed a general, and a very simple method of rectifying these curves. After him, Bernouilli, during his residence at Paris, showed how, by means of the integral and differential calculus, to determine their area and rectification. The invention of epicycloids is, however, ascribed to M. Reaumur, the celebrated Danish philosopher, during his residence at Paris, about the year 1674. These curves appeared to him to be such as best suited the teeth of wheels, constructed so as to diminish their mutual friction, and to render the action of the power more uniform; hence he was led to consider them, and to this purpose they have been applied. However, M. de la Hire makes no mention of Reaumur, and seems to claim the merit of this geometrical and mechanical invention. But M. Leibnitz, who resided at Paris in 1674, and the two following years, says, that the invention of epicycloids, and their application to mechanics, was the work of this Danish mathematician, and that he was esteemed the author of it.

EPISTYLE, (from επι, *upon* ϛυλος, *column*) in ancient architecture, a term used by the Greeks for what we call *architrave*, viz., a massive stone, or a piece of wood, laid immediately over the capitals of columns, from one to the other.

The epistyle is the first or lowest principal division of the entablature.

EPISTYLAR ARCUATION, a term applied to that method of building in which arches are thrown from column to column, instead of horizontal architraves.

EPITITHEDAS, (Greek επι τιθημι) a word used by the Greeks, to express the simæ, or cymatium, or crowning moulding of the entablature. By some the term is restricted to the upper member of a raking cornice.

EQUAL ANGLES, are those whose containing lines are measured by equal portions of equal arcs, described from the meeting of the two containing lines.

Equal Arcs. *See* Arcs.

Equal Circles, are those whose diameters are equal.

Equal Curvatures, are such as have the same, or equal radii of curvature. *See* Curvature and Curve.

Equal Figures, are those whose areas are equal, whether the figures be similar or not.

Equal Solids, are those which comprehend, or contain as much as the other, or whose solidities or capacities are equal.

EQUIANGULAR FIGURES, such as have equal angles.

EQUIDISTANT STRAIGHT LINES, are a series of parallels with equal intervals.

Equidistant Solids, are those whose intervals are terminated by parallel planes, at equal distances on the corresponding sides, comparing that of any two adjoining solids, with that of any other two adjoining solids.

EQUILATERAL (from *æquus*, equal, and *latus*, a side) having equal sides.

Equilateral Figure, that which has all its sides equal.

Equilateral Hyperbola, that in which the asymptotes are at right angles to each other.

EQUILIBRIUM, in mechanics, the equality of forces in opposite directions, so that they mutually balance each other; equipoise.

ERGASTULUM, among the ancients, a house of correction, or workhouse, where slaves, by the private authority of their masters, were confined and kept at hard labour for some offence. It was likewise called *sophronisterium.*

ESCAPE, a concave quadrantal moulding used to join two parallel members of different projections, as the shaft of a column with the fillet at its foot and junction with the capital.

ESCUTCHEON, a shield charged with armorial bearings. Decorations of this kind were much used in the later periods of Gothic architecture, carved on bosses, dripstones, spandrels, &c. The term is also applied to the metal plate on doors surrounding the key-hole, and to that from which the handle is suspended. Beautiful specimens, of excellent design and workmanship, are to be found in old mediæval buildings.

ESCURIAL, the palace or residence of the kings of Spain. The word originally signified a little village in Spain, situated in the kingdom of New Castile, twenty-two miles to the N. W. of Madrid. Here king Philip built a stately monastery, of the order of St. Jerome, held by the Spaniards as one of the wonders of the world. It was begun in 1557, and finished in about 22 years, at the expense of 6,000,000 of

piastres. The plan of the work resembles a gridiron, in memory of St. Quintin, who suffered martyrdom with that instrument.

The king and queen had their apartments there, the other parts were possessed by the monks.

The length of this superb palace is an oblong 740 by 580 Spanish feet, besides 460, for what may be termed the handle of the gridiron. The height of the roof is 60 feet, and every angle has a square tower 200 feet in height. The west front has 200 windows, and that of the east 366.

The Escurial has a very fine church, crowned with a dome, which is 330 feet, supported by four rows of pillars, and paved with black marble; containing 40 chapels, and 48 altars. To this church, Philip IV. annexed a beautiful mausoleum, called the *Pantheon*, or *Rotunda*, built on the plan of the temple of that name at Rome. It is 36 feet in diameter, and incrusted with marble; in which the kings and queens of Spain, who leave any posterity, are interred; the rest being laid in another vault of the same church, together with the infants and other princes.

ESTIMATE, a calculation of the expenses of a building, or other parts thereof, by measuring the drawings with a compass from a scale, and calculating the amount upon materials and workmanship. *See* BRICKWORK, CARPENTERS' WORK, JOINERS' WORK, &c.

ESTIMATION, the act of estimating a building, *See* ESTIMATE. A quick mode of estimating, or rather guessing at the expense of a building, is, to throw the whole into cubic feet, as if all the parts within the walls and roof were really solid, and calculating the whole at a certain rate per cubic foot; but this is so different in different places, and even in different times in the same place, that no certain ratio can be established: but where things are finished in the same way, in the same place, and at the same time, it frequently comes nearer to the truth than many real estimates, which are accepted far below value, in order to obtain the work. Though estimates sometimes come very near each other, yet the difference at other times is so preposterous, as to be one-fourth, or one-third of the whole amount, either owing to articles being overlooked, or to a difference of rates, or both.

ESTRADE (a French term, signifying a public road or highway) in building, a little elevation of the floor of a room, frequently encompassed with an alcove or rail, for receiving a bed; or sometimes, as in Turkey, it is only covered with fine carpets, for the accommodation of visitors of distinction.

ETRUSCAN ARCHITECTURE. The method of building practised by the ancient inhabitants of Etruria; from which it is supposed many of the peculiarities of Roman architecture took their rise, and the Tuscan order was borrowed. The origin and history of this people is involved in obscurity, as is also, to a great extent, their architecture. They seem to have been a mixed race, composed of Siculi or Umbri, of Pelasgi, and of a third race, of Lydian extraction, and to have attained to considerable eminence in the scale of nations, both in power and civilization. Although they had brought the arts to a great degree of perfection, we had, until recently, but little evidence of the fact; and, as regards their architecture, examples are still so scanty, as to afford us no precise notion of its character. We have no remains of temples, or other buildings of the kind; all such information is to be derived solely from their hypogæi or sepulchres, and the representation of buildings, to be found on the various utensils discovered therein. The remains above ground consist almost solely of ruins of walls surrounding the different cities, which remind us of the Cyclopæan erections at Tiryus and Mycenæ, consisting, as they do, of lofty heaps of stones of enormous size, fitted together in a compact form, but without either cramps or cement. Ruins of this nature exist at Cortona, Volterra, Fiesol, &c., in the first of which are some stones more than twenty-two Roman feet in length, and about five or six feet in height. The walls of Volterra are of a similar description. In the earliest examples, the stones are of an irregular polygonal shape, and in building were so laid as to have all their sides in close contact with the surrounding stones; remains of this kind of work are to be found at Cora near Velletri. Generally speaking, the stones were of rectangular form, and of various sizes, disposed in horizontal courses. There is at Volterra a gateway, called the Gate of Hercules, which has a fine arch composed of nineteen large stones. This leads us to remark, that the origin of the arch is very generally ascribed to Etruria, from whence it is said to have found its way into Rome. Be this as it may, the Etrurians were certainly aware of its principles, specimens of true arches and vaulting having been found in the remains, some of which are probably of early date. In a tomb at Cerœtri is a wall carried up somewhat after the shape of a Gothic arch gradually converging towards the top, but not meeting at the apex, a square channel being left between the two sides of the arch, which is covered over with a block of nenfro. This, however, is not a true arch but is similar to those to be found in Egypt and Greece, the building to which it belongs is on all hands allowed to be of very great antiquity.

From the description of Etruscan temples given us by Vitruvius, we learn that they were of an oblong form, the length being occupied by three chapels, of which the central one was the principal. The façades were similar to those of Greece, adorned with columns, pediments, &c., and the latter with sculptures in terra cotta. From the same author we likewise learn, that their private houses were buildings of some importance, having external porticos and vestibules like those of Rome; indeed, it is supposed that the atrium was borrowed from them by the Romans. Amongst the structures for which the Etrurians were eminent, are their tunnels, canals, and sewers, for the purposes of drainage and irrigation; roads, fortifications, and other works of an equally useful character. Remains of a cloaca have been discovered at Tarquinii, in which the arch is employed, and which is altogether similar to that at Rome; and at Volaterra are the ruins of a subterranean reservoir, 24 Roman feet high, 56 long, and 29 broad.

We have now only to notice the sepulchral buildings; which form by far the principal portion of the remains, and are found in great numbers, fresh ones being constantly opened at the present day. They seem to have been equally as numerous as the cities, and it would appear to have been an universal rule, that each city should have a place of burial for its dead in its immediate vicinity. To such an extent is this the case, that a modern writer lays it down as an axiom, that wherever there stood an ancient town, there you will find a cemetery; and wherever you find a cemetery, there will have stood likewise an ancient city. These sepulchres are, however, not all alike, their forms and situation varying according to the geographical, geological, and other characteristics of the site; in some cases they are cut out of cliffs below the city wall; at others out of more yielding soil, and, in cases where requisite, lined with masonry on the inside. Besides these excavated sepulchres, we have some of a more primitive and less imposing character, being nothing better than graves sunk a few feet below the surface, and covered with unhewn masses of stone. They are very similar to the Druidical cromlechs; which fact would intimate some connection between the Celts and Etruscans. Again, we find tumuli, another form of sepulchral monument, which is common to all parts of the world.

Amongst the cemeteries which have been explored, that at Vulci is one of the more important, and this, like many others, was discovered by mere chance, and was found to contain a vast number of antiques of various kinds. Those of Norchia and Castel d'Asso, the façades of which are covered with sculpture, were discovered in 1810; those of Bomarzo and Orte from 1830 to 1837. Of still later date are the discoveries of Savona by Mr. Ainslie, and of several others by Mr. Dennis, who has published a very interesting work upon the subject. There seems to be no scarcity of such monuments, for new discoveries are being brought to light every year, and would lead us to suppose that vast tracts of country were completely undermined by them. The cemeteries vary in size, some of them being of very great extent, and laid out like a city in streets and squares. Each has its peculiar kind of tomb, the most simple of which consist of mere conical pits about eight or nine feet in depth, and six in diameter. Next to these come the tombs, with a simple doorway opening in the side of the cliff, and leading into a small vestibule about five feet square, with a shaft carried up from the roof to the ground above, the opening of which is frequently covered over with a large stone. The vestibule gives access to the tomb, which is an apartment from twelve to twenty feet square, cut out of the rock, and supported in the centre by a low massive quadrangular pillar, or in larger tombs by four or more similar piers, as is shown in Inghirami's plates. Sometimes the tomb is divided into two parts by a thick wall cut out of the rock, which forms a means of support in place of pillars. In the side-walls of the tombs, and sometimes in the piers and partition walls, are two or more tiers of long horizontal niches in which the bodies were placed. Tombs of this kind exist near Corneto, Ferenti, and Cervetri.

Cemeteries of more imposing character are to be seen at Castel d'Asso, and the places to which we have above referred; of the former we give the following description from a popular work of the day. "At Castel d'Asso the tombs rise upon each side of a narrow glen, facing each other like the houses in a street. Each tomb being detached, and the cliffs in which they are hollowed being hewn to a smooth surface, and formed into square architectural façades, with bold cornices and mouldings in high relief, they bear a strong resemblance to dwelling-houses, their façades extending the whole height of the cliffs, which in some places rise as high as 30 feet. In the centre of each façade is a rod-moulding, describing the outline of a door, in many cases having panels recessed one within the other. This, however, is but the false semblance of an entrance, the real one being in the lower part of the cliff, which having been left to project when the façade was smoothed down, has been hollowed into a kind of small vaulted antechamber, open in front. The form of these monuments, as well as of the false door in the façade, tapers upwards, and the front recedes slightly from the perpendicular. Along the top of the façade runs a massive horizontal cornice, but receding from the plane of the façade. On many of the tombs there are inscriptions, some of which are still legible, graven deep in the smooth surface of the rock above the simulated doorway. On the inner wall of the little entrance-chamber, and immediately below the one in the façade, is a second false door, moulded like the former, but with a niche in the centre; and directly below this again is the real door leading into the sepulchral chambers, which, neither in grandeur of dimensions, nor elegance of details, answer to the external appearance of the tombs. They are quadrilateral, of various sizes, and rudely hollowed in the rock, having a flat or slightly-vaulted ceiling and ledges of rock against the wall for the support of sarcophagi. In some cases the sarcophagi have been sunk in the rock in two rows, side by side, with a narrow passage between them, and seem to have been originally covered over with tiles. In the interstices which separate the monumental façades, there are in many cases flights of steps cut in the rock, and leading to the plain above."

Tombs of a more decorative character exist at Norchia, adorned with pediments filled with sculpture, and Doric friezes, and bas-reliefs on the inner walls of the portico. The interiors, however, are of similar character to those at Castel d'Asso. At Bieda, are tiers of tombs hewn in terraces one above the other, and connected by flights of steps cut in the rock. Here also another peculiarity is presented, the tombs standing out from the rock completely isolated, and of similar form to dwelling-houses, having roofs sloping down on either side with overhanging eaves at the gable. The internal arrangement likewise bears a very great resemblance to that of dwelling-houses.

The tombs near Cervetri, opened in 1836, were originally covered with a large conical mound, and contain two apartments, an inner and outer one, separated by a partition, the latter being somewhat the largest, and the length of the two together measuring about 60 feet. On each side of the first chamber is a small cell cut out of the rock, the chamber itself being lined with masonry, and roofed over with a kind of Gothic vault, which springs at about three feet from the ground. Of this vault we have spoken above.

A curious range of sepulchres has been discovered at Chiusi, which, from the winding passages which lead from one tomb to another, presents the idea of a labyrinth, and caused it at one time to be considered a portion of the tomb of Porsenna, a description of which is given by Varro.

The following account is taken from the publication before referred to:—"The tombs to which we allude, are excavated in the conical crest of a broad hill, surrounded by a fosse about three feet wide, and lined on the inner side with large blocks of travertine, which thus form a wall measuring about 855 feet, this being the circumference of the base of the enclosed tumulus. The chief sepulchres open from the encircling wall; the largest, a circular chamber facing the south, and supported in the centre by a huge pillar hewn in the rock, is connected with the fosse by a passage of about 50 feet in length. Towards the south-east is a group of smaller chambers; close upon the fosse, and facing the south-west, is another, connected with the former by a passage about 45 feet long; while other smaller ones again, are situated all around, facing all the points of the compass.

"Above this tier is another, containing likewise several groups of chambers of different size and shape; and below the level of the fosse is a third tier, the chambers of which are, however, in a very ruinous state. Opening from the circular chamber facing the south, is a narrow passage, which winds by many a circuitous route towards the western group of chambers, and then turning again to the south, branches out into many side-passages. These passages were at first thought to form a regularly planned labyrinth, but their lowness being such as barely to allow a man to creep through on all-fours, the irregularity of their level, and the circumstance of the passage opening into the western group of chambers, breaking through one of the stone benches with which the walls of the chamber are lined, and on which the dead reclined, have subsequently led to the abandonment of this opinion, and of the idea of this being the site of the far-famed tomb of Porsenna."

We must not omit to mention that colour was used in these tombs as a means of decoration. At Tarquinii, they are all painted, but there is one, the Grotta Querciola, which in the design and execution of the pictures, surpasses all the others.

The walls are entirely covered with paintings illustrative of the social manners of the Etrurians, the colours of which, though now somewhat dim, must have been originally splendid. In the Grotta del Triclinio, hard by, the colours have retained their brilliancy, and the effect is described as perfectly dazzling by those who have beheld them in a bright light.

The Etrurians do not seem to have been a people of any great native taste, and are not to be compared with the Greeks in this respect; they preferred utility to beauty, and convenience to decoration. Some assert that all that is really beautiful in their monuments, emanates solely from Greece; but this we cannot suppose; they were destitute indeed of the creative imagination of the Greeks, and probably borrowed very largely from them, but at the same time we cannot suppose them to have been entirely devoid of originality.

For further information on this subject, we would refer to Michali and Inghirami, as also to the recent work of Mr. Dennis on the Cities and Cemeteries of Etruria. *See* ROMAN ARCHITECTURE.

EUANTHI COLOURS, in painting, a term used by the Greeks, to express what the Romans called the *floridi colores*, or such as had remarkable brightness: the duller and coarser colours, the Romans called *austeri colores*, and the Greeks *bathyci*. Of the first sort were cinnabar, lapis arminus, chrysocolla, minium, indigo, purpurissa, according to the Romans; but the Greeks, as we find by Dioscorides, made cinnabar one of the austere colours.

EVOLVENT (from the Latin *evolo*, to unfold) in geometry, the curve resulting from the evolution of a curve, in contradistinction to the evolute, which is the curve supposed to be opened or evolved.

EVOLUTE, or EVOLUTA, in the higher geometry, a curve first proposed by Huygens, and much studied by the later mathematicians: suppose a string, or flexible line, be unwound, so that the part unwound may be kept straight and in the plane of the curve, the extremity will describe a new curve, of which the first turn is the evolute.

The radius of the evolute, is the part of the thread contained between any point where it is tangent to the evolute, and the corresponding point, where it terminates in the new curve.

Every curve may therefore be considered as the evolution of another.

EURYTHMY, (from the Greek εὔρυθμος, *harmony*,) a certain majesty or elegance in the composition of the different parts of a building.

The word is Greek, and signifies literally a consonance or fine agreement; or, as we call it, *harmony*, of all the parts: it is compounded of ευ, *well*, and ρυθμος, *rythmus*, *cadence*, or agreement of numbers, sounds, or the like.

EUSTYLE, (from the Greek, ευ, *bene*, *well*, and ϛυλος, *column*) a disposition of columns in which the intervals are exactly two diameters and a quarter. This intercolumniation was most approved of by the ancients, as being a medium between the pycnostyle and areostyle.

Vitruvius, lib. iii. chap. 2. observes, that the eustyle is the most approved of all the kinds of intercolumniation, and that it surpasses all the rest in conveniency, beauty, and strength.

EXAGON, *See* HEXAGON.

EXCAVATING MACHINES, for digging and removing earth in extensive excavations, have occupied the attention of many ingenious men, and various machines for the purpose have been proposed and tried with different degrees of success. The great difficulty seems to consist in adapting any peculiar arrangement of mechanism which shall be capable of digging into the various sorts of earth. Were it only to operate upon a uniform mass, the task would be of comparatively easy accomplishment.

Amongst others who have devoted much time and capital in the attempt to overcome these difficulties, Mr. G. V. Palmer applied himself to the construction of machines of this kind. In 1830 he took out a patent "for a machine to cut and excavate the earth." This invention is designed, by the application of steam-power, to loosen, dig up, and remove into a cart, earth from a canal or other cavity, and to move itself forwards as the excavation proceeds. In principle, its leading arrangement resembles the dredging-machines employed in clearing the beds of rivers and harbours; but it has several appurtenances, such as *picks*, for loosening the earth; *cutters*, for separating it; and *scrapers*, for filling it into scoops or elevators; the latter convey it into the cart by which it is carried away. The machine is mounted upon four wheels, and gradually moves forward upon a temporary railway, as the excavation proceeds. The moving power is applied to the axis of a fly-wheel, and to the same axis is fixed a drum or pulley, around which passes an endless pitched chain, giving motion to another drum or pulley, which revolves in bearings fixed to the upper ends of two long cheeks or supports. Around this second drum passes another endless chain, by which a third drum or pulley, of a quadrangular figure, is set in motion, and which turns on an axis in the lower ends of the long cheeks; to this last-mentioned chain are fastened a series of earth-scoops, which are successively brought into operation in taking up the earth. So far, the machine resembles the common ballast-engine; we have now to describe how the several actions of picking, digging, and projecting the earth are effected. A third endless chain is actuated by the drum on the main axis, and gives motion to a spur-wheel; this spur-wheel drives another toothed wheel attached to the fore-wheels of the carriage, and thus the carriage gradually advances. By an ingenious system of levers, connected to a crank on the main axis, a row of pick-axes, a row of cutters, and a row of scraping-shovels, are alternately brought into action. When the pickers have descended and loosened a portion of earth, the cutters follow, and separate it from the mass, and this separated portion is immediately afterwards drawn forwards by the scraping-shovels into the scoops, which, by the action of the machine, are brought into the required position on one of the sides of the revolving quadrangular drum; and filled scoops thence proceeding to the top of the machine by the revolution of the attached endless chain, discharge their contents into a cart or waggon to be conveyed away. The same gentleman patented another engine for this purpose in 1832. This consisted of an excavated cart and plough united, to be worked by horses or other power. The cart-wheels are made considerably wider than those in common use, and the interior portion of the ring of each wheel is made into a series of earth-boxes; these earth-boxes are made to open inwards, and also towards the centres of the wheels. Underneath the cart, immediately adjoining each wheel, is placed a plough, for raising and turning the earth into the boxes, as the cart is moved forwards; the wheels at the same time turning round, bring up the earth, and deliver it into the body of the cart. When a sufficient load has been thus deposited in the cart, the ploughs are raised from the ground by means of a lever, and then the cart can be drawn in every respect as a common cart, to the place intended for the deposition of the excavated earth, where it is to be unloaded by withdrawing a pair of bolts, which allow the bottom of the cart to fold downwards sufficiently to permit the earth to escape. There are many circumstances where

the application of excavating machines of this kind might be employed to advantage, but though the use of them in the extensive excavations of railway works has been many times attempted, they have not been found to answer so well in practice as to bring them into general employment.

EXCAVATION, (from the Latin *ex*, out, and *cavus*, hollow) the act of hollowing or digging a cavity, particularly in the ground.

The excavation for the foundation of a building, by the Italians called *cavatione*, is settled by Palladio at a sixth part of the height of the building, unless there be cellars under ground, in which case he would have it somewhat more.

But this proportion is vague, and contrary to experience and reason. Good firm gravel, clay, or rock, forms as good a foundation at a foot or 18 inches from the surface, as at any greater depth; while swampy or boggy land is not good at any depth. *See* DIGGING and FOUNDATION.

EXCHANGE, a building where merchants resort to transact business. The principal commercial cities of Europe and America have edifices appropriated for this purpose, and the Bourses of Paris, Amsterdam, Antwerp, and other continental cities, and the Exchanges of London, Liverpool, New York, &c., are distinguished for their beauty and convenience. In London there are three buildings of this kind; the Corn Exchange—the Coal Exchange—and the Exchange of London, *par excellence*, the Royal Exchange. The two first are appropriated to the particular branches of commerce indicated by their names, and are more especially resorted to by persons therein engaged; the Royal Exchange is the general place of assembling, at a certain hour of the day, of the merchants and traders of London. Here meet together men from all parts of the world, and here are settled transactions of commerce of a magnitude inconceivable by those unacquainted with the subject. There are few merchants in the city but make it a rule to attend the Exchange daily, or, as it is termed in commercial phraseology, "to go on 'Change." We propose to give a brief description of each of these places of mercantile rendezvous.

The CORN EXCHANGE is situated in Mark Lane, and consists, in fact, of two buildings adjoining each other, and known respectively as the Old and New Corn Exchange. Business, however, is carried on in both, and together they are considered as the "Corn Exchange."

The new building, as we have before observed, immediately adjoins the older one, which still continues to be made use of, and which may therefore with propriety be briefly described here, if only for the purpose of affording some kind of comparison between the two. "The lower part of the structure is an open colonnade, whose pillars are of the modern Doric kind, but the entablature has a plain frieze, and its architrave is singularly narrow for the order, or indeed for any order whatever. There are eight columns, with an iron palisading between them; displaying, however, a very peculiar arrangement, four of them being placed in pairs, but in such a manner, that, beginning to reckon from the south end, we find them placed thus: first, a pair of columns at that angle, then three single columns, then another pair, and at the north angle another single column, forming altogether five inter-columns, corresponding with which are as many windows in each of the two stories forming the upper part of the building over the colonnade; which are quite plain, with the exception of the centre one on the first floor, which, in addition to other dressings, has a pediment."

There is no wall behind these columns, and the space within is open to the street, forming a court rather than a hall, the centre space of which is not covered by a roof. With this difference, it resembles the similar part of the plan in the new building, having, as that has, three intercolumns at each end, and five on each side; and it further resembles it in the great depth of the ambulatory around it. The building, though making little pretension to architectural character, except what it derives from its columns and their arrangement, has, in its general effect, a degree of picturesqueness both unusual and pleasing, especially as there is a second range of columns between those in front and the area of the Exchange itself.

The New Corn Exchange was erected in 1828, from the designs of Mr. G. Smith, the architect of St. Paul's School, and exhibits a very tasteful and appropriate application of the *Grecian* Doric.

In point of design, this facade merits investigation, because, whatever else may be alleged against it, no one can object to it, that it is either a direct copy, or an assemblage of copies, that is, of parts entirely borrowed from other buildings, without other novelty than what they derive from their combination with each other.

The colonnade forming the centre, (which being an hexastyle in antis, gives the same number of intercolumns as an octostyle,) does not constitute a loggia, or even a mere corridor; for, as may be seen by the plan, the space between the columns and the wall is occupied, except where the entrances occur, by a sunk area screened by the stylobate. This area being barely equal to one diameter, the colonnade is much shallower than usual, and therefore likely to be censured, on that account, by those who consider a certain depth of space behind the columns to be an indispensable requisite for their proper effect, and invariably demanded in all situations and under all circumstances.

In the present instance, the very moderate distance at which the wall is placed behind the columns, occasions greater breadth of surface, as the light falls upon that as well as on the columns themselves; which would not be the case were the wall so far back that the columns would relieve themselves entirely against the shadow of the parts beyond them. At the same time, the columns receive a greater portion of reflected light, and thus contrast more distinctly with the shadows which they cast on the wall itself, and which produce an agreeable variety and equipoise of light and shade, according to the sun's elevation, when it shines on this (the west) side of the building. But that to which, more than anything else, this façade is indebted for its classical air and architectural beauty, is the entire absence of windows within the colonnade. Not only do such apertures—unless introduced very sparingly indeed—destroy repose, by frittering what requires to be preserved nearly an unbroken surface, but they show themselves in a situation where their serviceableness is greatly lessened. Besides which, the colonnade or portico itself seems misplaced, being overlooked by the rooms behind it.

To return to the immediate object of our description: we may observe, that the wall is not entirely plain, it having slightly projecting antæ or pilasters corresponding with the columns, and the faces of those in the centre serve partly as a ground upon which the jambs of the large door are raised. This door is a feature not only important for its size, but tasteful in design—bold and simple, yet at the same time carefully finished.

In the frieze, wreaths composed of ears of corn are substituted for triglyphs; and even had they not elegance of form as well as novelty to recommend them, they would still have a propriety and significance which we rarely meet with in those similarly-shaped decorations of laurel transferred to modern buildings, from the entablature of the monument of Thrasyllus.

The cornice here given to the order is rendered less cold and scanty than usual by the addition of a cymatium above the corona, ornamented with lions' heads, that slightly break its upper line. Much of the peculiar character arises from the unusually lofty blocking-course, surmounted in the centre by a podium bearing the following inscription:—'Corn Exchange, erected 1828, according to act of parliament, 7th George IV. Chap. 33.' This podium is, in turn, surmounted by a piece of sculpture representing the royal arms, grouped with implements symbolical of agriculture. Thus the upper part of the front acquires considerable variety of outline, and somewhat of a pyramidal form, together with distinctly marked individuality of character. Instead of being at all at variance with the style adopted, the part we are now considering is not only consistent with, but seems to give additional expression to all the rest; at the same time that it takes away from it that air of direct imitation which it is so difficult to avoid without endangering, if not destroying, the classical physiognomy intended to be preserved.

Whether, in his treatment of the wings, the architect has successfully overcome this last-mentioned difficulty, is what we have now to inquire. As far as regards the order itself, that is kept up with sufficient strictness, and the mode in which the antæ are applied, deserves commendation. Had these been merely coupled, after the usual fashion, the effect would have been rather formal and monotonous; besides which, it might not improperly have been objected, that such duplication was at variance with the arrangement of the columns. But by compounding, instead of pairing them, and placing the broader anta at the outer angle, while the other is made to project slightly upon it, both a due expression of strength and solidity is kept up, a certain degree of play and variety is obtained, although there appears to be nothing at all new in the idea itself, except that here the two united faces are of unequal breadth—an irregularity converted into a merit by its obvious propriety.

"The windows, which entirely occupy the space between the antæ, may be considered as assuming the character of small loggiæ, whose intercolumns are filled in with sashes. In style, therefore, they harmonize with the general design far better, perhaps, than anything else that could have been devised for the same purpose; the chief objection to be made in regard to them is, that somewhat less plainness—not to call it severity of style—would not have been amiss, and would have prevented the small antæ of the windows from appearing a repetition of the larger ones on a diminished scale.

"The upper story of the wings, to which we now come, display more invention and decided novelty than any other part of the building; and although exhibiting somewhat of unusual forms and combinations, the style here preserves its characteristic energy, boldness, and breadth. Although, too, the parts themselves are simple, they acquire much picturesque complexity from the lofty position in which the windows are placed, being thrown further back, owing to which the pedestals detach themselves with considerable projection. In addition to the variety thus produced, we have that arising from the attic itself, if it may so be termed, being both loftier than the pedestals, and narrower than the compartment of the front below; from both which circumstances result great contrast and diversity of outline.

"The interior calls for very little description or remark, the walls being perfectly plain, and their being no other decoration of any kind than the columns, which are of very slender proportions, and have deep capitals, composed of ears of wheat. Above the centre space within the columns, is a lantern with vertical lights; and those on each side have seven skylight compartments in their ceilings. The north wing contains a tavern and coffee-room, and the opening in the south wall of the other wing communicates with the old Corn Exchange."—*Public Buildings of London.*

The Coal Exchange is a new building erected in Thames-street, near the Custom House, and completed so lately as the month of November, 1849.

The importance of the vast trade in that precious mineral to which Great Britain owes so much of her prosperity, may well demand that the merchants and others trading in coal, should have their own Exchange. The enormous extent of this trade can hardly be conceived, or its value in a pecuniary sense estimated.

"In respect to its natural supply of coal," says McCulloch, "Britain, among the nations, is most singularly favoured; much of the surface of the country conceals under it continuous and thick beds of that valuable mineral, vastly more precious to us than would have been mines of the precious metals, like those of Peru and Mexico; for coal, since applied to the steam-engine, is really hoarded power, applicable to almost every purpose which human labour directed by ingenuity can accomplish. It is the possession of her coal-mines which has rendered Britain, in relation to the whole world, what a city is to the rural district which surrounds it—the producer and dispenser of the rich products of art and industry. Calling her coal-mines the coal-cellars of the great city, there is in them a supply which, at the present rate of expenditure, will last for 2,000 years at least; and therefore a provision which, as coming improvements in the arts of life will naturally effect economy of fuel, or substitution of other means to effect similar purposes, may be regarded as inexhaustible."

The former Coal Exchange being quite unfit for the purposes required, and the inconvenience felt by the merchants frequenting it much complained of, an enlarged site was purchased by the corporation of London, for the erection of a new Exchange. This site afforded a frontage next Lower Thames-street of 113 feet, and a similar frontage next St. Mary-at-Hill. The building is erected from the designs of Mr. Bunning, the architect to the corporation, and is so arranged as to give an increased width to the two thoroughfares above-named. It presents two distinct elevations, connected by a tower, placed within the re-entering angle formed by the two fronts.

The façades of the building are of very simple, yet bold and effective design; and, with the exception of the cornice, but few projections are introduced. The fronts in Thames-street and St. Mary-at-Hill, are respectively about 112 feet in width, by 61 feet in height. The unequal form of the plot of ground on which the Exchange stands, is skilfully masked at the corner by breaking the mass of building, and introducing the circular tower before mentioned. This tower is 109 feet high to the top of the gilded ball, and 22 feet in diameter at the lowest part, and is divided into three stories. The lowest story, containing the entrance vestibule, is of the Roman-Doric style of architecture; and presents a striking peculiarity in the arrangement, to which we must advert. The wall of the tower not only contains the vestibule by which entrance to the hall or rotunda is attained, but serves also as a centre to flights of steps, which lead, on either hand, to a landing on the first story of the building. From this landing, a spiral staircase is carried up in the tower to the other stories. The first story is of the Ionic order, carrying an entablature, and is lighted by windows. The top story, 15 feet in diameter, is ornamented by pilasters, with windows between; the roof rising to a cone, and being crowned with a gilded ball. The front of the whole is faced with Portland

stone. Entering the rotunda, the attention of the visitor is immediately arrested by its beautiful effect, and extremely novel arrangement. It forms a circle of some 60 feet in diameter, and is crowned with a dome, or, in fact, double dome, as a lesser cupola rises from the eye of the great dome to the height of 74 feet from the floor. The dome rests on eight light piers, the space between each pier being divided by stanchions into three compartments. There are three galleries, and from these galleries, entrance is obtained to the numerous offices in the building. The galleries are peculiarly constructed, and entirely composed of iron, embellished with symbols of the coal trade. Iron, indeed, has been most extensively made use of; the stanchions, brackets, ribs, and eye of the dome, are all of iron, and above 300 tons have been used in the building in the several parts. Each rib, of which there are 32, is 42 feet 6 inches long, is cast in one length, and weighs on the average two tons. The arrangement of pateræ in the stanchions, brackets, and soffits of galleries, is original and good. The ornament chiefly used is a cable, twisted about in various patterns, and the balustrade to the galleries is of loops of cable, broken at intervals by the introduction of the City arms. This rope-ornament has perhaps been used in too great profusion, for it is displayed on the stanchions, gallery-railings, soffits, and every place where it could possibly be introduced. The frame-work to the offices is of wood, and panelled with rough plate-glass. By this means, they receive light from the great dome of the hall. The dome itself is glazed with large pieces of ground plate-glass of great thickness, the glass of the small upper dome having an amber tint. The chief public offices surrounding the Rotunda are those appropriated to the offices of the corporation, whose business it is to collect the coal dues; the factors' board-room, the weighers' society, and the merchants' and factors', among whom Sir James Duke, lord-mayor of London at the time of the opening of the Coal Exchange, holds a very prominent position.

The floor of the Rotunda is composed of inlaid woods, disposed in form of a mariner's compass, within a border of Greek fret, and in its appearance is beautiful in the extreme. In its construction are employed upwards of 4,000 pieces of wood of various kinds, comprising black ebony, black oak, common and red English oak, wainscot, white holly, mahogany, American elm, red and white walnut, and mulberry. The whole of these materials have been prepared by Messrs. Davison and Symington's patent process of seasoning woods, to which we have alluded under the word Desiccation.

The same desiccating process has been applied to the woodwork throughout the building. The black oak introduced is part of an old tree which was discovered imbedded in the river Tyne, where it had unquestionably lain between four and five centuries. The mulberry wood, of which the blade of the dagger in the shield of the City-arms is composed, is made of a piece of a tree planted by Peter the Great, when he worked as a shipwright in Deptford dockyard.

The coloured decorations of the Exchange are peculiarly characteristic, and the entrance vestibule, in particular, is extremely rich and picturesque in its embellishments. Terminal figures, vases with fruit, arabesque foliage, &c.; all of the richest and most glowing colours, fill up the vault of the ceiling, through an aperture in which is seen that of the lantern, adorned with a figure of Plenty scattering riches, and surrounded by *figurini*. Over the entrance-doorway, within a sunk panel, are painted the City-arms. Within the Rotunda the polychromatic decorations immediately arrest the eye. The range of panels at the base of the dome, and the piers which carry the dome, are all fully and harmoniously decorated. Commencing with the piers in the lowest story :— It will be seen that the Raffaelesque decorations are very rich in character. In each pier a scroll supports and encircles four compartments; the lowest are semi-circular panels, within which are painted symbolic figures of the principal coal-bearing rivers in England : the Thames, the Mersey, the Severn, the Trent, the Humber, the Aire, the Tyne, &c. Small oblong panels, with marine subjects, are a little above the symbolic figures just described; and above these again, within borders of flowers of every kind, are figures symbolical of Wisdom, Fortitude, Vigilance, Temperance, Perseverance, Watchfulness, Justice, and Faith. These figures are the most prominent objects in the decorations of the piers in the lower story, and in circles above them are painted groups of shells; whilst at the top, in semi-circles corresponding with those at the base of the piers, snakes, lizards, and other reptiles, are introduced. In the first story, the leading feature in the arabesques is a series of views of coal-mines, including the air-shaft at Wallsend, Percy Pit Main Colliery, Wallsend Colliery, Regent's Pit Colliery, &c. Groups of fruit and flowers are in small circles just above the views, and in oblong panels beneath the latter the series of nautical "bits" is continued. At the base, in each pilaster, are representations of different specimens of Sigillaria—a fossil found in coal formations. In the second story, the largest panels contain figures of miners engaged in different parts of their labours, but these figures we think are not so well executed as other portions of the decorations. Nautical subjects, clusters of fruit and flowers, are introduced among the arabesques. The third story contains, within oval panels, miners at work, picking the coal, &c. : flowers and small landscapes add to the richness and variety of the decorations on this floor; and both in this and the lower, *calamites*, (fossils from the coal formations,) are depicted amongst the arabesques. The twenty-four panels at the springing of the dome, of which we have before spoken, have oval compartments painted in them, surrounded by a gracefully flowing border of extremely rich and varied design, being light ornaments on a dark ground. The spaces within the oval borders are coloured of a turquoise blue tint, on which is painted a series of representations of different fossil plants met with in the coal formations. This portion of the decoration is extremely striking and appropriate; and, we need scarcely say, the representation of the plants are strictly correct. These were painted in encaustic by Mr. Sang, from the drawings of Mr. Melhado, (a pupil of the architect,) taken from specimens in the British Museum. A staircase leads to the hypocaust, which was discovered in excavating for the foundation, a remnant of the time when the Romans ruled here. A visit to this will amply repay the lovers of antiquity, and its minute agreement with the details of such constructions given by Vitruvius, should be noticed.

The artificers' work generally were performed by Mr. Trego; the iron-work by Messrs. Dewer; and the woodwork was seasoned by Messrs. Davison and Symington's patent desiccating process. The floor of the merchants' area was laid down by the first-named of these gentlemen, Mr. Davison.

The cost of this Exchange was about £40,000.

The Royal Exchange, in general, has been fortunate in finding historians, still the current descriptions are, for the most part, imperfect and incorrect, and utterly without the sanction of official authority.

Like everything in the City, the existence of the Royal Exchange is owing to individual enterprise. This is the spirit and essence of commercial prosperity. The merchant

is generally the architect of his own fortune; his pursuits necessarily bring him into contact with his fellow-men; and thus, while the principle of association obtains with him, and expresses itself in the guild and the corporation, in his own person he maintains a special individuality. To him who would indulge personalities. and portray characteristics, a visit to the City would afford many examples—some strange and odd enough, but all striking and strongly marked. In other pursuits of life there is more or less of a professional costume, which sinks the man in the official; but the merchant pleases himself, or acts upon early associations, in his dress and conduct. His success mostly depends, indeed, upon the personal. Gresham, the founder of the Royal Exchange, is an illustrious example of the truth of these remarks, and another instance of the great works that may be accomplished by the zeal, activity, and perseverance of an individual.

To Sir Richard Gresham, however, father of the Sir Thomas Gresham, whose name has become a "household word" to the citizens of London, the merchants of this great metropolis are indebted for the first serious attempt to found an Exchange. Before this time, the merchants met together in the open air in Lombard-street, exposed to the many inconveniences of such a place of assembling. In the reign of Queen Elizabeth, Sir Thomas Gresham, who determined to carry into effect what his father had been unable to do, proposed to the corporation, in 1564, "That if the City would give him a piece of ground in a commodious spot, he would erect an Exchange at his own expense, with large and covered walks, wherein the merchants and traders might daily assemble, and transact business at all seasons, without interruption from the weather, or impediments of any kind." This offer was accepted, and the new building, when completed, was visited by the Queen, who "caused the same to be proclaimed by sound of trumpet, the *Royall Exchange*, and so to be called from thenceforth, and not otherwise." Sir Thomas Gresham, who died in November, 1579, bequeathed the whole of this edifice, and its various appurtenances, after the death of his wife, "jointly for ever to the corporation of London and the Company of Mercers," upon trust for various purposes.

The fabric erected by Gresham was almost entirely destroyed by the great fire of London in 1666. Measures for the erection of a new building were, however, promptly taken, and in October 1667, King Charles II. laid the base of the column on the west side of the north entrance of the second Exchange; and, on the 31st of the same month, the first stone of the eastern column was laid by his brother, the Duke of York.

The popular notion has always been that Sir Christopher Wren was the architect of this Exchange; this is not the fact, the architect was Edward Jerman, one of the surveyors to the City in 1666. As this is a matter on which much difference of opinion has existed, we think the insertion of the following evidence from a letter in "The Builder," will definitively settle the question. The writer states, that the extracts we have given below, were taken from the records of the City, and of the Mercers' Company, and from them are obtained the following facts, which leave no doubt whatever that Jerman, and not Wren, was the architect of the late Royal Exchange.

"That on the 19th———1666, the commissioners appointed to the work, summoned to their assistance, Mr. Mills and Mr. Jerman, the City surveyors. Again at a joint committee, held on the 25th April, 1667, the following minute is ecorded :—

"The committee, concluding it very necessary at this meeting, to make choyce of a surveyor for directing and overseeing the building of the Royal Exchange, and assisting them in carrying on that designe to the best advantage, as to substantiallnesse, ornament, and frugality; and forasmuch as Mr. Mills, the City surveyor, hath declared that hee cannot perform that worke alone, and the committee being very sensible of the greate burden of businesse lying upon him for the City all this time; and considering that Mr. Jerman is the most able knowne artist (besides him) that the City now hath: therefore the committee unanimously made choice of Mr. Jerman, to assist the committee in the agreeing for, ordering, and directing, of that worke; and, having declared the same unto him, hee, after much reluctancy and unwillingness (objecting, it might bee thought an intrenchment upon Mr. Mills his right,) at length accepted, being assured first by the Lord Mayor and the committee, that itt was no intrenchment, that this wholle committee, at all times, would acquit him from any scandall in that behalfe; then the committee ordered the clerke to acquaint Mr. Jerman with all the proceedinges of this committee about the said building."

After this appointment Mr. Mills's name does not occur again, and the works evidently proceeded with great rapidity, for they were finished within three years and a half from the period of Jerman's appointment.

On the 9th December occurs the following entry. "The committee considering that Mr. Jerman, who was chosen surveyor for rebuilding the Exchange in April last, hath not yet received any gratification for drawing drafts and directing the building; they therefore ordered that £50 shall be payed him upon account until further consideration of his merits."

These extracts, I think you will agree with me, prove that Edward German (or Ierman as sometimes spelt) was the sole architect. In these records Sir Christopher Wren is spoken of, under date of the 7th Jan., 1670, as "Dr. Wren, Surveyor general of His Majesty's workes."

The building erected by Jerman, was publicly opened for business on the 28th of September, 1669, the expense of its construction having amounted to £80,000, which was defrayed in equal moieties by the City and the Mercers' Company.

This structure also was doomed to fall by the same element which had proved fatal to its predecessor, for on the night of the 10th of January, 1838, it was discovered to be on fire, and in the course of the night, though not entirely destroyed, was so much damaged, that for all purposes of usefulness the destruction may be said to have been complete.

The architecture of the building thus destroyed has been variously estimated; by some decried, by others praised; but probably it merited the extravagant praises of the one party as little as it deserved the severe criticism of the other.

The four orders of the quadrangle were richly decorated, with the basements, arches of the walks, the cornices over them, the niches, statues, pillars, circular windows, entablature, pediments, and balustrade, all in correct proportion and arrangement. Its principal front was towards Cornhill; and on each side there were Corinthian demi-columns, supporting a compass pediment; within each of which were niches containing statues of Charles I. and II. in Roman habits, by Bushnell. Within the quadrangle there were twenty-four niches in the intercolumns, with statues of English kings and queens, most of the kings before Charles II. being sculptured by Cibber. The centre of the area had for some time a statue of Charles II. by Grinlin Gibbons, which was subsequently displaced for one by Spileer, habited in the Roman style. In an obscure position under the piazza, the statue of Gresham, too, had its niche; and nigh to it, that of one, whose modesty would have been better content had his merit received no such acknowledgment—Sir John Bernard; to whom, in his

lifetime, the memorial was erected as a mark of civic respect, but who could never bring himself to visit the walks afterwards.

The destruction of this building having deprived the merchants of London, for the second time, of their great place of resort, they were obliged temporarily to assemble in the space attached to the Excise Office, in Old Broad Street. This was, of course, attended with much inconvenience to those accustomed to attend 'Change, and it became therefore a matter of pressing importance to remove that inconvenience by the erection of a new building, fitted in every respect for its purpose, and worthy the merchant-princes of the first metropolis in the world.

In preparing to re-erect the Royal Exchange, many interests had to be considered—those of the Underwriters of Lloyd's, the Royal Exchange Assurance Company, and the shopkeepers who had occupied the ground-floor. An act of parliament was also necessary; this was applied for, and obtained. By this act, which received the Royal assent on the 10th of August, 1838, the Joint Gresham Committee were empowered to purchase and remove all the buildings to the eastward, extending nearly to Finch Lane, and to raise a sum of £150,000 upon the credit of the London Bridge Trust.

After considerable delay, the Gresham Committee issued their advertisements for designs for the new building, but in doing so, unfortunately did not avoid the errors into which so many similarly-constituted public bodies have fallen, under similar circumstances. There is little doubt but that the Committee intended a fair and honest competition, but with *not singular* bad management, they so contrived matters, as to bring down on themselves a storm of indignation from all sides, and to disgust not only the competitors, but the public in general.

The system pursued of late years in the management of architectural competitions, has been attended with manifest evils, and fraught with gross and palpable injustice to the profession. Hastily and inconsiderately commenced, under the control of persons unfitted to sit in judgment on the various designs referred to their decision, they have in too many instances been attended by results, as injurious to the best interests of art, as unfair and unjust to its professors.

In making these remarks it is not intended to attack the principles upon which competitions are based; properly conducted, their tendency is unquestionably, not only to call out the talent and genius of the experienced artist, but to rouse a spirit of emulation in the young professor, as an assistance in encouraging rising merit, which without such a stimulus might possibly remain undeveloped, or, without such a means of exercise, unknown and unappreciated.

There may be many advantages attending architectural competitions, but there is so total a want of security, under the operation of the present defective system, so general an impression existing, whether justly or not, that fairness and impartiality in the decisions cannot always be relied upon, that the great body of the profession hold themselves aloof from entering an arena where fair play is, to say the least, doubtful. The competition for the Royal Exchange, it is to be lamented, afforded another proof, if proof were wanting, of the truth of these observations.

It is not our purpose to enter on a discussion of the merits of a controversy which filled many pages of the periodicals more especially devoted to recording matters connected with architecture and building, but we think we cannot pass to a description of the New Exchange without slightly noticing the manner in which the design for it was selected, or its architect appointed.

The following are extracts from the—

"*Resolutions of the Gresham Committee, as to Instructions to the Architects.*

"1. That architects be invited to offer designs for the rebuilding of the Royal Exchange, in general competition, and that premiums be offered for three designs adjudged by the Committee to be the best.

"3. That the new building be of the Grecian, Roman, or Italian style of architecture, having each front of stone of a hard and durable quality.

"6. That a specification be required to accompany each design, giving a general description of the building, and such other information as cannot be clearly shown on the drawings, stating also what stone, or other material, are proposed for use in the different parts of the building, and specifying particularly the estimated expense of carrying the designs into execution in the most substantial and complete manner in every respect for occupation, the expense not to exceed £150,000.

"10. That for the design for which the Committee shall award the first premium, the sum of £300 shall be given; that for the second design the sum of £200; and for the third the sum of £100. The successful competitor, to whom the first premium is awarded shall not be considered as having necessarily a claim to be entrusted with the execution of the work; but if not so employed, and his designs are carried into execution, a further sum of £500 shall be paid to him—the Committee retaining possession of all the drawings for which the premiums have been given.

"11. That if reasonable doubts should arise in the minds of the Committee as to the practicability of carrying into execution the successful design for the amount of the estimated expense of the building, the Committee shall be at liberty to call upon the party to give sufficient and satisfactory proof of the accuracy of the calculations, and to withhold the premium, and reject the designs unless such proof be furnished."

After issuing these Instructions, the Committee appointed three architects—Sir Robert Smirke, Mr. Gwilt, and Mr Hardwick, to examine and advise on the designs which might be sent in. Above fifty competitors appeared, and the above gentlemen, after due examination, made a report to the Committee, from which we extract the following passages.

"In the first class, those that we think may be executed for £150,000, we beg to report as follows:—

First	No. 36
Second	„ 43
Third	„ 37
Fourth	„ 33
Fifth	„ 57

"In the second class, or that in which we consider the cost would vastly exceed the sum of £150,000, equal impracticabilities of execution with those of the first class are to be found; and, notwithstanding the very great talent they exhibit, there are circumstances of inconvenience and unsuitableness which would bring them, as we conceive, into the predicament of being unadvisable for adoption. We wish it, therefore, to be understood, that we report on them respectively as the works of very clever artists, who have produced pieces of competition in which, besides the circumstances above-mentioned, stability arising from solid bearings for upper apartments, and other essential matters, have been sacrificed to grand architectural features.

"The designs in the second class, in our estimation of their order of merit, are as follows:—

First	No. 50
Second	„ 46
Third	„ 27

"We again venture to state to the Committee the difficulties which have attended the making of the report herewith submitted, and which, but for the unanimous decision at which we have arrived, we confess, might have left doubts in our minds, if our view had not been confined by the Committee to the expenditure of a given sum."

On receiving this report, the Joint Committee met at Mercers' Hall on Friday, the 18th October, to consider the report, and again inspect the designs, and came to the following resolutions :—

"Resolved,—That the premiums be awarded to the architects who have produced the plans numbered as under—

No. 36 the first premium . . . £300
„ 43 the second „ . . . £200
„ 37 the third „ . . . £100

being those reported by the architects as the three best designs.

"And it was resolved, that Sir R. Smirke, and I. Gwilt, and P. Hardwick, Esqrs., having stated in their report upon the respective merits of the plans selected by them, that they cannot recommend any one to be carried into execution, this Committee doth request them to take the 1st, 2nd, and 3rd plans, as selected by them, into consideration, and prepare a plan and specification for a new Royal Exchange, such as in their judgment should be carried into execution, having reference, at the same time, to the printed instructions issued by this Committee to the architects."

The following were the architects to whom the premiums were adjudged.

No. 36, £300, to Mr. William Grellier, district surveyor, 20, Wormwood-street.

No. 43, £200, to M. Alexis De Chateauneuff, of Hamburgh; and Mr. Arthur Mee, of Carlton Chambers.

No. 37, £100, to Mr. Sydney Smirke, of Carlton Chambers.

The architects of the remaining designs of the first class.

No. 33, Messrs. Wyatt and Brandon.
„ 46, Mr. Pennethorne.

The architects of the second-class designs, which were considered too expensive.

No. 50, Mr. T. L. Donaldson.
„ 46, Mr. Richardson.
„ 27, Mr. David Mocaotta.

The next step taken by the Committee was to appoint Mr. George Smith, the City-surveyor, and Mr. Tite, to inquire into the eligibility of some one of the designs selected by the umpires for the premiums. Mr. Tite, however, refused to act, and the onus devolved on Mr. Smith alone. This gentleman submitted a report to the Committee, in which he advised the rejection of the whole of the designs; and the Committee acting on this advice, without ceremony threw the supposed successful candidates overboard, and boldly selected six other architects, whom they requested to send in designs for the contemplated building. The gentlemen so honoured by the Committee were Sir R. Smirke, Mr. Barry, Mr. Gwilt, Mr. Hardwick, Mr. Cockerell, and Mr. Tite, the whole of whom, excepting the two last, declined accepting the invitation, being doubtless influenced to such course by the bad faith observed to all parties by the Committee. What also added to the public dissatisfaction, was that rivalry or competition between Mr. Cockerell and Mr. Tite was considered out of the question, from their previous connection. Thus the whole matter evidently settled down in Mr. Tite being selected finally to prepare the design for the new Royal Exchange.

That design we shall now proceed to describe, as given by Mr. Tite, himself, in his explanation to the Committee :—

Extent and Site.

The total length of the building is 293 feet 6 inches, from the columns of the portico on the west, to the pilasters at the east end; the width of the portico is 89 feet 6 inches; the extreme width at the east end, at the broadest part, is 175 feet, and the width through the centre, from north to south, is 144 feet.

The building is placed in the centre between the south front of the Bank, and a mean line of the irregularities presented by the houses on the south side of Cornhill; the east and west fronts are at right angles to the centre line, and, of course, the angle formed by the intersection of the north and south fronts, with the east and west fronts, is the same; by this means the building, though not rectangular, is regular in the plan.

Arrangement.

Gresham College occupies the north-west angle of the building on the principal story, and is entered from the north.

The Royal Exchange Assurance occupies the south-west angle, and the space over the west end of the colonnade, on the one-pair floor, and is entered from the south side of the loggia, under the portico.

The London Assurance occupies the greater part of the south front on the principal story and is entered from the south.

Lloyd's fills up the remainder of the east and north fronts of the principal story, and is entered in three places, viz., from the east and the north-east corner, and from the north.

There is a small additional staircase and entrance to the principal lecture-room of the Gresham College (which I propose to use for the exit from the lectures only) and this opens into the loggia under the portico.

The commercial room proposed to be attached to Lloyd's, and which, in a letter from Mr. Barnes, of the 26th February, I am requested so to manage as that it might be appropriated for offices, if not eventually required for the above purpose, has been accordingly placed by me on the principal story on the north side. If not required by Lloyd's, I should propose to convert this room into a double range of offices, one lighted from the street, and the other lighted from the area of the Exchange, each office having a room over in a third floor; the access to these rooms would be by a distinct staircase and entrance on the north, for which a distinct shop must be taken. The mean width of this commercial room is 39 feet, and its length 96 feet; allowing, therefore, for an 8 feet passage in the middle, it would provide for 12 sets of offices, each 16 feet by 15 feet.

The shops and offices are very material features of any design for this building, for, under the 62nd section of the act for providing a site for the Royal Exchange, the Gresham Committee are bound to compensate any party holding a lease in any part of the old Royal Exchange, unless the owner or lessee is reinstated. As regards the offices this would probably only be the value of the difference between the reserved rent and the actual rent, and not a matter of much importance; but unless the valuable trades and occupations round the Exchange are reinstated, the question would become a very important one, because it would involve the good-wills of the parties. The mere question of reinstatement, however, is not the only one; for it is clear the revenue to be obtained from the shops, after the expiration of the present leases, must form a very important item in any income to be derived from the building. In order to meet these requirements, and still, I hope, in no way to injure the design, I have placed the shops or offices on a level with the

street, round the north, south, and east sides; and, inasmuch as I found that in the old Royal Exchange there were shops in three of the entrances, and as I could very conveniently arrange a few in the east entrance of my design, I have placed six there. Let the claims, however, arise as they may, with this plan now under discussion, there could be no difficulty in meeting them all, for the area of all the shops and offices of all descriptions, in the ground-floor of the Old Exchange, amounted to 8 106 feet only, whereas, in this plan, the shops and offices provided, exclusive of the part appropriated to Lloyd's, to the Gresham College, the London Assurance, and the Royal Exchange Assurance, exceeds this quantity by 1,087 feet, the total being 9,217 feet. The increased value of all this, and the exact nature of the accommodation, will, however, be further explained under other heads of this descriptive particular.

Accommodation.

Gresham College.—In considering this department of the building, I was placed in considerable difficulty, not only from the total absence of instructions, but because I found, as well amongst the committee as in society, very considerable differences of opinion on the subject.

After much reflection, I have, however, arranged what I hope will be considered a complete establishment for most purposes, and it is as follows:—On the north side of the Exchange, about 45 feet from the west end, is an entrance with a small hall and staircase. In this hall a porter would be placed, who would prevent the admission of improper persons.

The entrance-doorway is large, and over it is placed a shield containing the arms of Sir Thomas Gresham. This entrance and hall are also quite distinct, and, like all the other parts or distinct portions of the design, it is separated by party-walls. On the first landing of the staircase is a porter's room, which would also serve for umbrellas, coats, or cloaks.

On the one-pair, or principal floor, is a lecture-room or theatre, of a horse-shoe form, the dimensions being 46 feet, 6 inches, by 36 feet. To this is added a library or lesser lecture-room, 25 feet by 24 feet; a lecturer's or librarian's room, 19 feet by 15 feet 6 inches; apparatus-rooms, 16 feet 3 inches, by 11 feet: with a water-closet and washing-room; and two rooms over the librarian's, and apparatus-rooms for some resident servant.

The theatre would seat 250 persons on the floor, and 200 more might be conveniently seated in the gallery. It is probable, however, that for many lectures or continuous courses, this might be too much, but for some it might be too little. I have, therefore, placed the library at the back of the theatre, by which, in the latter case, the accommodation might be increased, or in the former it might be sufficient in itself for such purposes. The result, therefore, is this, that for an auditory of 40 or 50 persons, the library would be sufficient; beyond that number, and up to 450 persons, the theatre would be the proper place; if a larger number were expected, the partition dividing the library from the theatre might be removed, (as is shown in the plan) by sliding it into the wall, when, by removing the lecture-table a little further back, 50 persons more might be accommodated. Beyond this extent of 500 persons, it is probably undesirable to carry it further.

If, however, I have erred altogether, and have provided too much, it is easy to diminish it; or if it is determined to abandon this site for this purpose, the space so complete and isolated would readily let by itself, or might be combined with the unappropriated offices in the north-west angle immediately under the theatre. It remains to be added, that I have also provided ample vault-room in the basement of this establishment, and a second staircase connected with the theatre, and only intended to be used on a crowded occasion, for the dismissal of so large an audience as 400 or 500 persons, and for a private approach or retreat for the lecturer.

Royal Exchange Assurance.—This establishment in the old building occupied apartments in the mezzanine, and on the one-pair floor. The net area being 5,235 feet, exclusive of passages, staircases, water-closets, kitchen, and rooms in the roof. I have had many meetings with the governor on the subject, and at length I received, so late as the 4th instant, a list of the rooms, of which I have attached a copy to this description.

The total area in this is 6,284 feet, but omitting the store rooms and kitchen for the sake of comparison, the net quantity is 5,894 feet. My plan gives this so nearly, and the dimensions of the rooms also correspond so generally with the requirements, that I need not occupy the time of the Committee with any further description; but, in addition, I have added what appears to me obviously necessary, viz., strong rooms and cellars in the basement.

As the heights of the floors of this part of the building differ in some respects from the general section, I beg to add them here, and they are as follows, viz.: The ground-floor is 2 feet 6 inches above the level of the floor of the Exchange, and 6 feet above the street; under this is a lower ground story, the height being 10 feet with vaults under.

The ground-floor will be 13 feet, high, the mezzanine 10 feet, the one-pair floor is 18 feet, except where there are rooms over, when this will be 13 feet.

London Assurance.—I attach a copy of the instructions received from this company to my letter of the 6th March, addressed to Mr. Barnes. The total quantity of space required is 5,553 feet, exclusive of waiting-rooms, water-closets, &c.; as some of the rooms seemed extravagant in size, I have arranged them somewhat less, and the company express themselves satisfied with my dimensions, the total being 4,834 feet.

Lloyd's.—With regard to this very important establishment, I beg a reference to my letter to Mr. Barnes, of the 6th instant, to which I attach a copy of the new instructions forwarded by their architect. The total quantity of space occupied in the old Exchange by this company, exclusive of staircases, was 7,914 feet. The space now required is 13,781 feet, exclusive of passages, staircases, water-closets, urinals, &c.; but this includes the commercial room, which is 4,050 feet. The dimensions of the several apartments in my plan are very nearly consistent with their requirements, and the total result the same.

The arrangement of the rooms is best understood by a reference to the plan of the one-pair floor, and I believe it to be quite in accordance with the wishes of the Committee.

Shops.—I propose that each shop shall have a cellar below, and, with very few exceptions, a mezzanine over. The average height of the shops will be 14 feet, the basement-floor 12 feet, and the mezzanine 10 feet. Each shop will be secured by party-walls, and roofed with iron beams and arches under the one-pair floor. The water-closets will be in the basements, there will be a separate flue in each shop, and room for the fire-places; and I propose that each shop and room shall be warmed by an open, or Arnott's stove, of the same pattern.

The staircase will be circular, and of cast-iron. Staircases of this kind, though not much known here, have been extensively used in Paris, and are admirably adapted for such purposes. I have paid every attention to the mode of light

ing the deeper shops, and I hope I have succeeded in obviating all reasonable apprehension on that subject. The shops without mezzanines, are one in the south front, one in the north front, and four in the eastern entrance to the Exchange. In the area, in the latter case, they are left out, to allow of light being obtained over the shops to the back parts of the other premises.

Exchange.—The Exchange is entered from four arched openings in the centre of each side; the form is a parallelogram, and the inner area exactly a double square. This form has many advantages, both in point of convenience and elegance over the old form, and is also better adapted to the shape of the ground.

As to the level of the floor of the Exchange, I have heard many opinions; but it appears to me to be of the greatest importance, that it should be as nearly level with the street as possible. From the natural fall of the ground, however, which is quite gradual, but amounts to 3 feet 6 inches in the length of the building from east to west, it is impossible to avoid a few steps at the north, south, and west entrances. This is an advantage at the west end, as it gives height and character to the façade or portico; the exact effect and extent of this fall of the ground is shown in my north and south elevations. In the shops the steps are avoided, because they can follow the natural inclination of the ground.

Basement.—Much of the basement (or vaults,) is occupied by the establishments over the respective divisions, and I have added some to the lesser shops, but there is still a large space which may be let off, as the basement of the old building was. I have lighted the basement by area gratings in the pavement of the Exchange, exactly as formerly.

The public vaults are approached by two staircases, which are placed in the eastern entrance. The central area is proposed to be left without a basement; it would be difficult to keep it dry, and I do not know any use to which it could be applied which would pay for the cost.

Style of Architecture.

This is naturally one of the most important considerations in the design, and one in which I have most to regret the limited time I have had to consider this most extensive and difficult composition. It appears to me, that a building for essentially commercial purposes should present the character of grandeur, simplicity, and usefulness. In this way, the universally acknowledged good effect of the Bourse at Paris has been obtained. In that building the lines are simple and unbroken, and the large arched windows surrounding the walls behind the columns have all the character of shops or offices. The west front of the Exchange of London, as in that of Paris, must be the principal feature, the other sides being bounded by buildings.

Another difficulty arises from the shape of the ground; because any tower placed to agree with the lines of the south front must disagree with the lines of the east and west fronts, which are in different planes; and such an object, when seen from a distance, or from the area of the Exchange, would produce an effect that would be discordant and unarchitectural, because it would bring into distinct notice a fact which it should be the business of the architect to conceal. For a long time I contended with this difficulty, because I was anxious to place the tower or towers in the south front, but it was impossible to get over the irregularity; it would, indeed, have been easy to have concealed this defect in the drawings, or have kept it out of notice, but the result, when built, would only have ended, in my judgment, in disappointment and failure. For these reasons, and with these views, I have composed my design as it is now exhibited. I have placed a portico at the west end, and the tower at the east. The south and north fronts exhibit unbroken lines of entablature, with a repetition of arches of the same character for the shops, offices, and entrances. We are deficient in England, of specimens of architecture of this unbroken kind: were I to adduce instances, I should quote the National Gallery, as affording an illustration of the bad effect of broken and detached masses, and the Reform Club, of the excellent effect of continuous and unbroken ones.

The portico would be very superior in dimensions to any in this country, and not very inferior to any in the world. The width, from outside to outside of the 8 columns, is 90 feet, and the height, from the ground to the apex of the pediment, is 74 feet 6 inches. The portico of St. Martin's Church is 64 feet wide and 58 feet high; that at the Post-Office 76 feet wide and 67 feet high; and from these dimensions a fair comparison may be made of the relative size of the two porticos.

The height of the order used in this edifice is 50 feet, and the height of the tower, to the top of the vane, is 170 feet. From the point of view prescribed by the instructions, the tower is not seen. Had I been at liberty to have removed the station further to the westward, as to Mansion-House-street, or the Poultry, the tower would have been seen over the portico, and the effect of the composition thereby greatly improved. The sections and view show the exact character of the interior of the Exchange, the lower story is a colonnade of the Doric order, the columns are 34 inches in diameter; the upper order is Ionic.

Specification of the nature of the work.—The examination of the foundations, which I ventured to suggest, has proved that the nature of the sub-soil is of the best kind for supporting a large building. At an average of fifteen feet from the surface, a very compact gravel is found. For the sake of perfect uniformity, I should excavate sufficiently for a few feet below this; and by a uniform bed of concrete, of the thickness of six feet over the whole surface, a most certain and safe foundation would be made. The gravel is full of water, and therefore the drainage must be carefully considered.

Your conditions require a general specification, but, without going into full technicalities, I am at a loss to furnish a specification of any value. I intend everything to be executed in the best manner. All external work to be faced with Portland stone; all the horizontal divisions that require it, for the purpose of security from fire, to be constructed with iron beams and brick arches; and the ceiling and floor over the colonnade constructed in the same manner. The timber used to be all Baltic timber, English oak, or African teak. Everything to be sufficiently and completely finished in all respects.

Sculpture.—I have not introduced much sculpture into this design, because the estimate would not allow of it; and I have, therefore, aimed at a style which did not require it to any extent. The sculpture introduced as essential to the architecture, embraces the five panels in the attic of the south front, and the two figures at the west end. The panels in the south front are intended to represent Britannia, supported by the principal cities of the empire receiving the representatives and productions of the four quarters of the world; the two seated figures in the west front, are emblematical of Peace and Abundance. There are several shields of arms, which though not falling exactly under the head of sculpture, I think it desirable to mention, and they are as follows:—the escutcheons on the key-stones of the three great arches of the west front, are the arms of Queen Elizabeth, Charles the II., and Queen Victoria. These arms are repeated in the panels

of the attic at the east end. In the north and south fronts, on the keystones of the centre arches, the arms are those of the City, the Mercers' Company, and Sir Thomas Gresham.

Estimate.

I estimate the cost of this edifice, as thus described, including the sculpture, at the sum of £143,800.

Income.

I have estimated with great care the income to be derived from the various shops, offices, and public establishments, proposed in the several floors of the building, by comparing dimensions and other circumstances, with the previous lettings, and by the actual value derived from my own experience; and I am of opinion that the total net annual value, if let on lease, would amount to the sum of £8,718 per annum. In addition to this, if the space allotted to Lloyd's commercial room on the north side, and that to the London Assurance on the south side, were arranged as offices, each set having two rooms, one over the other, as suggested in an early part of this statement, though the estimate would be increased £3,000, I have no doubt this annual income might be raised to the extent of £800 per annum, making a total income of £9,500 per annum.

In the drawings themselves, I have carefully laboured to follow out the instructions under which I undertook this competition. The views are strictly confined to the points of view prescribed: in the colouring of the views themselves, and in the drawings of the adjoining buildings, I have laboured to be accurate, and to give as nearly as I could, the actual effect of this edifice, if it were constructed. I cannot but feel that a more elaborate style of architecture would have been productive of more picturesque effects, and it would have been easy to have produced them; but I have ventured to come to the conclusion, that nothing but plain grandeur and elegant simplicity is consistent, either with the means at the disposal of the committee, the purposes and uses of this building, or its situation in the very heart of the City of London.

We have given at length Mr. Tite's own description of the building, as affording the most perfect and complete explanation of every particular connected with it, and also as showing the many requirements he had to meet, and the various interests he had to provide for. It is due to him to say, that he has certainly succeeded in satisfying all parties, in the convenience of his arrangements for individual benefit, while he has added to the public buildings of London an edifice in every respect worthy the first community in the world. On one part of the design much discussion took place at the time, viz., whether the area of the new Exchange should or should not be an open court, as in the old building. In the instructions issued to the competing architects by the Gresham Committee, this was insisted on, and, as we are informed, in compliance with the general opinion of the merchants and bankers of London. With submission, however, we are strongly inclined to believe that the merchants and the Gresham Committee might have left this matter, with benefit, to the discretion of the architects offering designs, with whom it would have remained to demonstrate the advantage or defects of either mode of construction, whether open or covered.

It is worthy of remark that the Bourse at Paris, and at St Petersburg, the Exchanges of Dublin and Glasgow, and almost all modern structures erected for a similar purpose, are, we believe, roofed in; one advantage of which is, that the whole of the area is available, let the weather be as unfavourable as it may, consequently, the same superficial extent can accommodate a far greater number of persons than where it is only partially sheltered, and where a considerable portion must frequently be altogether useless, as far as actual serviceableness is concerned. The present arrangement therefore is to be approved of only where what is thus sacrificed, with regard to mere convenience and utility, is amply atoned for by what is gained as to architectural character and effect.

We do not deny that a *cortile*, whether surrounded by columns or by arches, and whether partially or entirely so, is favourable to scenic effect and display, and, farther, admits of very great variety as to plan and design. This is sufficiently testified by examples in Italian buildings, where cortiles frequently constitute the most striking and beautiful parts, generally picturesque and piquant, though not always unexceptionable in design. But then it does not exactly follow, that because a cortile is beautiful as such, it is eligible for a purpose requiring more than a sheltered corridor around the open part; for, although that kind of shelter is sufficient for a place of *passage* to and fro, it certainly does not seem to be sufficient for one intended for the assemblage of a concourse of persons, not on particular occasions, when, in case of the weather proving unfavourable, the company may be protected from it by awnings provided for the emergency, but daily, throughout all seasons of the year. When a place of the kind already exists, it may conveniently and properly enough be applied just as it is to the purpose of an Exchange; its inconvenience may, then, be put up with as unavoidable. But there is no qualifying circumstance, to reconcile us to a defect studiously adopted, voluntarily and with premeditation, to the exclusion not only of positive convenience, but likewise of originality of design. Either our climate is most unjustly reproached, not only by foreigners, but by ourselves, or it ought at once to have banished all idea of rebuilding the Royal Exchange upon the plan of the former one, as regards that very principal part of it where the merchants will daily assemble, and to which all the rest is to be considered as merely supplementary.

Be it any improvement or not, all our lately built markets are floored with flagstone pavements, and covered in from the weather, shaded from the burning sun in summer, as well as sheltered from rain and snow in winter; nor do we believe that either the occupiers of them, or their customers, at all regret the change which has taken place. Nevertheless, with instances of that kind before their eyes, not in the Metropolis alone, but at Liverpool, Newcastle, and other places, the merchants of London have decided that they are to meet for business as heretofore, within an area only partially and imperfectly protected from the weather. Even beneath the colonnades, they must be more or less exposed to wind and rain, and be inconvenienced by the throng of persons; whereas, by converting the central space into the part more particularly appropriated to the transaction of business, the sides, which might still be separated from it by colonnades, would be left free for persons passing in or out, without interruption to those engaged in business.

There may possibly be contrary reasons for not adopting a mode of building securing the advantages here pointed out by us; but they have not been brought forward by others, nor can we divine what they can be. Hardly can it be objected, that any plan of the kind would destroy all peculiarity of character, by converting the Exchange itself into merely a spacious hall, lighted from above, which, however it might be decorated, would, in its general effect, resemble any other public apartment of the same dimensions; because, although it would no longer be a cortile—an open space enclosed by façades of external architecture—it might be kept altogether different from anything we are accustomed to, in interior architecture, and appropriately rendered *sui generis*.

It will appear a very singular pendent to the above observations, that we should have to insert the following petition to the Gresham Committee, from the very parties to oblige whom this "uncovered" area was insisted on.

"The undersigned Merchants of the City of London are of opinion, that, in the construction of the new Royal Exchange, sufficient attention has not been paid to the comfort of those who attend the same, and beg most respectfully to submit to the Gresham Committee the following alterations, which are necessary before they can assemble there without danger to their health and personal comfort. The alterations suggested are:—1. That the area be covered in. 2. That some remedy be provided to remove the cold damp from the pavement. 3. That a remedy be also provided to protect them from the currents of air."

The above petition has been signed by Messrs. Barings, Rothschilds, Heath, Morris Prevost, Doxat and Co., Lemme and Co., and some hundreds of the first firms in the city. After much discussion in Committee, the clerk was directed to communicate to the memorialists:—

"That in the month of September, in the year 1838, before the Gresham Committee took any steps whatever as to the erection of a new building, they applied by circular to most of the leading merchants and brokers, requesting their opinion as to whether the new Exchange should be a covered hall, or partially open, as in the original Exchange of Mr. T. Gresham, and in the one recently destroyed; that besides, the Committee took every opportunity, by personal inquiry, of ascertaining the wishes of their fellow-citizens on the subject; that the result of the circular, and of these inquiries, was, that a large majority wished the Exchange to be partially open, as heretofore, alleging the great noise in the Bourse at Paris, and the necessity for ventilation of the most free kind, as their reasons for the decision; that in consequence of this determination, they directed a part of the merchants' area to be left uncovered as before, but that, for greater shelter, they further directed that the covered space should be increased from one-half, (the proportion of the space covered in the late building,) to two-thirds; and that the architect of the present edifice had strictly followed out these instructions; and, for these reasons, the Committee could not comply with the wishes of the merchants; that, with regard to currents of air, the committee had directed such inner doors to be put up, at the north and south entrances, as might check the draughts, at the same time providing that such doors should not interfere with the extensive uses of the area of the Exchange, as a thoroughfare to all the neighbouring streets, the Bank, the Stock Exchange, and other important public and private buildings of the neighbourhood."

We have given the above, as *apropos* to the question of a roofed or unroofed area, though this is hardly the proper place for a petition delivered some months after the Exchange had been opened for business. Such a petition, however, proves clearly the justice of the observations we, in common with the great body of the profession, have urged to the central space of the building having been left uncovered.

To return from this apparent digression.—After much consideration as to whether the material employed should be magnesian limestone, similar to that used for the Houses of Parliament, it was determined that the whole of the exterior of the building, with the exception of the socle or stylobate (which was to be of granite) should be Portland stone of the best quality. This point having been decided, the Gresham Committee at length found themselves in a position to enter on the contracts for the new structure. About fourteen of the principal builders were applied to, and sent in tenders; and those of Messrs. Webb for the first contract, (the excavation and concrete foundation); and of Mr. J. Jackson for the second (the super-structure),—were accepted. The first was for £8,000—the last for £115,000.

In excavating the merchants' area, (originally intended to have been left solid,) for the purpose of extending the basement beneath that part of the plan: a number of antiquities were discovered, beneath what was the west wall of the former building; in particular, the remains of some Roman structure were found, which proved, on examination, to have been built on a very large pit or pond, irregular in shape, but about 50 feet in length from north to south, 34 in breadth, and 13 in depth. This pit was filled with hardened mud, in which were immense quantities of bones of sheep, of bones and horns of stags, also numerous fragments of the red Roman pottery, usually called Samian ware, pieces of glass, and glass vessels, broken lamps, &c., and several copper coins, two of the emperor Vespasian, the remainder of Domitian—all of which antiquities were, by the terms of the contract, reserved for the Gresham Committee. On Monday the 17th January, 1842, the first stone was laid by His Royal Highness Prince Albert, with much state and ceremony, a full description of which appeared in the newspapers of the day; and the works then proceeded with such rapidity, that in three years from that date the new Royal Exchange was completed—a very brief space of time for such a work, especially considering that it consists entirely of stone.

On Monday the 28th of October, 1844, the Exchange was opened by Queen Victoria in person. The "pomp and circumstance" of such a ceremonial are not for a work like the present, they have been duly chronicled by those publications which record so faithfully and so minutely events like these: but the following observations, which appeared in one of the newspapers at the time, seem so pertinent to the subject, that we think their insertion here not inappropriate. "The present ceremonial," says the writer, "will, in many things, resemble that which was presided over by the 'Virgin Queen:' for state and its observances partake of the traditional, and are transmitted down with comparatively slight changes. But in all else how different! What an empire! and what a metropolis! How vast the increase in all that constitutes the strength of nations, in the England of Victoria, since it was the England of Elizabeth! The empire is one of many tongues and nations; the population of its chief city is counted, not by thousands, but by hundreds of thousands; and as for the commerce of the realm and city of Gresham's royal mistress, it was, as compared with that of the England and London of to-day, but as the rivulet to the ocean; its development has been as vast as that which could bring 'Dodona's forest from an acorn cup.' Between the day on which a Queen of England passed through the Temple-Gate to open the first Royal Exchange—and the hour which will see another Queen of the same fair land pass along the same road on the same august errand—great has been the destiny of England among the nations of the world! At this point the mind naturally goes forward to the future, and asks itself the question, what will be the state of this 'crowning city,' of the traffickers of the earth, when three centuries shall have passed over the now white walls, the fair chambers, and sculptured portico, of the new Exchange? What will be the condition of the empire, when the generation that gazes on the pageantry of to-day, shall—with many succeeding ones—be mingled with the dust? They are solemn questions; and, happily for us, can find no answer from human intelligence. The misery of Adam, when the angel, in Milton's immortal epic, revealed to him the doom of the future race of man, is but a type of what would be felt

by all, if the coming time were not, with infinite wisdom and mercy, hidden from our ken. The past we know; the present we can govern; for the future we can only hope, making our actions such as to render a cheerful hope justifiable. Let the spirit of commerce, then, when it takes up its new abode, work with the energy and activity that have always marked it. Above all, let it preserve that integrity and commercial honour which have been so long the pride of the English merchant, and then will it have done the best to secure a still further development of the wealth, extent, power, and numbers of that realm over which Elizabeth watched, and which Victoria now rules; queens, who, differing in much, yet resemble each other in the extent to which they have commanded the loyalty and affection of the people; and in this also—that the commercial activity of their respective ages received the countenance of both. In its reference to our history, the opening of the NEW ROYAL EXCHANGE by QUEEN VICTORIA, is one of the most interesting events of modern times."

We must not conclude our description of this magnificent building, without reference to the sculpture with which the new Royal Exchange has been adorned. That by Mr. Richard Westmacott, in the tympanum of the pediment at the west front, deserves the earliest and highest mention, both from its position and its merit. Allegorical in subject, it nevertheless avoids the objections to which such compositions are generally liable. It consists of seventeen figures, carved in compact limestone, and, with two exceptions, modelled as entire and detached figures. The centre figure, which is ten feet high, represents Commerce; with her mural crown, her cornucopia, bee-hive, and other accessories. Her left hand holds the charter of the Exchange, her right rests on part of a ship; two dolphins and a shell forming her pedestal. The groups on either side consist, on the right, of three British merchants in their civic robes—as lord-mayor, alderman, and common-councilman; two Asiatics, a Hindoo, and a Mahommedan, in appropriate costume; a Greek bearing a jar; an Armenian scholar, and a Turkish merchant; and, on the left, of two British merchants examining some woven fabric shown to them by a Persian; a Chinese; a sailor of the Levant; a negro; a British sailor cording a bale of cotton, &c.; a super-cargo, or factory agent. The opposite angles are filled with anchors, jars, packages, and other nautical and commercial emblems. The arches of the upper story are decorated with the arms of various nations, according to the order determined at the congress of Vienna—the arms of England occupying the centre of the eastern side. The sheltered walk for the merchants also has the ceiling and sides panelled, painted, and emblazoned with the arms of countries and monarchs; namely, Edward the Confessor, Edward III., Elizabeth, and Charles II. In the south-east angle there is a statue of Queen Elizabeth, and in the south-west a statue of Charles II.

It only remains now to speak of the statues of Queen Victoria inside the building, and of the Duke of Wellington without. The latter is a bronze equestrian figure, by Chantrey, and was composed of the metal of the guns taken in battle, contributed by the government, and valued at £1,500. The cost of the statue itself was £900. It was completed on the anniversary of Waterloo, the 18th June, 1844, when the inauguration took place, at which the King of Saxony, who was in England at the time, attended. The marble statue of the Queen, by Lough, in the centre of the merchants' area, was not placed on its pedestal until the 27th of October, 1845. An interesting fact is recorded by historians respecting the statue of Gresham. During the raging of the great fire of 1666: "When the fire was entered," writes the old chronicler, "how quickly did it run round the galleries, filling them with flames; than descending the stairs, compasseth the walks, giving forth flaming volleys, and filling the court with sheets of fire. By-and-by the kings fell all down on their faces, and the greater part of the stone building after them, *the founder's statue alone remaining.*"

It is a remarkable fact, that this statue was again saved in the fire of 1838.

The gates of the Exchange are exceedingly handsome. They are made of wrought-iron, the decorations being cast-iron. In the centre of the gates, on either side, are the arms of the City of London, and of the Mercers' Company, with the cipher of Sir Thomas Gresham, (T. G.,) very ingeniously introduced. In the ornamental heads of the gates, the rose, thistle, and shamrock appear entwined.

After the publication of the first portion of this article, the following paragraphs appeared in *The Times;* and we think we cannot better conclude our account of the Exchanges of London, than by recording so high and so well-deserved a compliment, to the designer of the Coal Exchange:—"A piece of plate, weighing 222 ounces of silver, was presented to the City architect, for services which are sufficiently indicated by the inscription: 'Presented to I. B. Bunning, Esq., by the coal-factors and merchants of the City of London, as a testimonial of their admiration of his genius and judgment in the erection of the Coal Exchange, and of his urbanity throughout the progress of the structure; which is not more approved of by those for whose use and convenience it was designed, than by the public at large, for its taste and elegance as a work of art. Anno Domini M.D.CCCL.' The plate was presented by Mr. Harris, as the organ of the coal-factors, with an appropriate speech. In addition to this pleasing compliment to Mr. Bunning, the coal-factors and merchants have signed a declaration, for presentation to the Corporation of the City, of their satisfaction of all the accommodations provided for them by means of the New Coal Exchange, which they attribute to a union of talent on the part of the architect, which has enabled him to produce an edifice which, whilst it embodies all the requirements of the coal-factors and merchants as men of business, is, at the same time, in design, taste, and judgment, the admiration of the numerous strangers who daily visit it, as one of the chief objects of interest and of Art in the City of London."

EXEDRÆ, (from the Greek εξεδραι, *a parlour*) among the ancients, places wherein the philosophers, sophists, and rhetors, held their conferences and disputes. They are supposed to have been recesses in the walls, or little chapels, answering to what we call *chapters* in the cloisters of monks, or collegiate churches.

Also applied to an apse or recess in a building, or to a projecting porch, in short, to any addition to a building. In the early Christian church, the term is applied to all the buildings within the consecrated enclosure which were detached from the church. Such were the baptisteries, vestries, diaconica, schools, libraries, and such like.

EXENTRIC, or ECCENTRIC, (from the Latin *eccentricus*) in geometry, a term applied to two circles or spheres, in which, though in some measure the one is contained within the other, yet the two have not the same centre, and consequently their surfaces are not parallel. The word is opposed to *concentric* where they are parallel, and have the same centre.

EXOSTRA, in the ancient theatre, a place where such parts of the play were recited as were supposed to be acted privately in the house.

EXPANSION, (from the Latin, *expando*) that degree of increment, which a body is susceptible of extending in one

or more of its dimensions by heat. Bodies of every kind, as far as we are acquainted with them, are expanded in bulk by heat, and are contracted by cold; and to this law there are but few exceptions, which will be noticed in due time. The expansions, or the increments of bulk, are not exactly proportional to the increments of heat in the same body; nor are different bodies expanded alike by the like elevation of temperature. Thus, if a quantity of water be increased one inch in bulk by the communication of ten degrees of heat, the communication of twice or thrice as much more heat will not cause it to expand two or three inches more. Also, if a rod of gold, and another similar rod of glass, be heated to the same degree, their increments of bulk, arising thereby, will not be equal, the gold expanding more than the glass.

Of the three principal states of natural bodies, viz., solids, liquids, and elastic fluids, the solids are expanded least; the liquids are expanded more than the solids; but the elastic fluids are expanded a vast deal more than the liquids. The knowledge of the precise quantities of these expansions of bodies is of great use in philosophy, in mechanics, and in other scientific subjects; hence no pains have been spared by philosophers to investigate and ascertain them; various instruments have been contrived for that purpose; innumerable experiments have been instituted; and a great many useful results have been obtained. Of these results we shall now endeavour to give a regular and distinct account.

The instruments which have been contrived for the purpose of measuring the expansions of solids arising from an elevation of temperature, are called *pyrometers.* The objects which must be had in view in the construction of pyrometers, are to form a steady frame, wherein solids of a certain length may be applied either successively, or several of them at the same time; some contrivance by which those metallic bodies may be heated to any required degree; and a mechanism capable of measuring the increase of bulk which is caused by the heat; and this may be accomplished by means of multiplying wheels, by levers, by screws, by a microscopical micrometer, or otherwise.

Some of the first determinations of the expansion of bodies, that may be considered as being sufficiently accurate, were made by Mr. Ellicot, with a pyrometer of his contrivance. Mr. Ellicot determined the proportional expansions of seven metallic bodies by the same elevation of temperature. They are as follow:—

Gold.	Silver.	Brass.	Copper.	Iron.	Steel.	Lead.
73.	103.	95.	89.	60.	56.	149.

Mr. Smeaton contrived a much better pyrometer, and with it he determined the expansions of several solids. M. De Luc also contrived a pyrometer of a peculiar construction; but Mr. Ramsden's pyrometer is superior to any other contrivance of the kind.

The following table shows, in parts of an inch, how much one foot's length of different substances is expanded by 180° of heat, Fahrenheit's scale, between the freezing and the boiling points of water. To the first seven substances (which were examined in Mr. Ramsden's most accurate pyrometer) there are added the expansions for a single degree of heat. The others were determined by Mr. Smeaton with his pyrometer.

	Fahrenheit's Scale. By 1°	Fahrenheit's Scale. By 180°
Standard brass scale, supposed to be Hamburg brass	0.0001237	0.0222646
English plate brass in form of a rod	0.0001262	0.0227136
English plate brass in form of a trough	0.0001263	0.0227386
Steel rod	0.0000763	0.0137368
Cast-iron prism	0.0000740	0.0133126
Glass tube	0.0000517	0.0093138
Solid glass rod	0.0000539	0.0096944
White glass barometer tube		0.0100
Martial regulus of antimony		0.0130
Blistered steel		0.0138
Hard steel		0.0147
Iron		0.0151
Bismuth		0.0167
Copper hammered		0.0204
Copper eight parts, with tin one part		0.0218
Cast brass		0.0223
Brass sixteen parts, with tin one part		0.0229
Brass wire		0.0232
Speculum metal		0.0232
Spelter solder, viz., of brass two parts, and of zinc one		0.0247
Fine pewter		0.0274
Grain tin		0.0298
Soft solder, viz., lead two parts, tin one		0.0301
Zinc eight parts, with tin one, a little hammered		0.0323
Lead		0.0344
Zinc or spelter		0.0353
Zinc hammered half an inch per foot		0.0373

Iron, instead of being condensed into a smaller bulk, expands in its transition from a fluid into a solid state; so that a quantity of iron occupies more room in the solid form than it does in a fused state.

Dr. Wollaston, in order to form some estimate of the comparative rate of expansion of platina and palladium, says, "I riveted together two thin plates of platina and palladium, and observing that the compound plate, when heated, became concave on the side of the platina; I ascertained that the expansion of palladium is in some degree the greater of the two. By a similar mode of comparison I found that palladium expands considerably less than steel by heat." *Phil. Trans. for* 1805.

It must be remarked, with respect to the expansion of glass, that sometimes glass tubes are extended more than solid glass rods; their dilatation, however, is not constant; for tubes of different diameters, or of different sorts of glass, are expanded differently by the application of like degrees of heat.

Wood is not much expanded longitudinally, that is, in the direction of its fibres, by heat; and this is particularly the case with deal and other straight-grained wood. Probably, upon the whole, the longitudinal expansion of wood is less than that of glass. It has been observed, (especially by Dr. Rittenhouse, *Trans. of the American Phil. Society,*) that very dry and seasoned wood, if not exposed to a very high or to a very low temperature, will expand in length pretty regularly; otherwise its expansion by heat, and its contraction by cold, are very irregular; for they seem to depend partly upon the heat, and partly upon the moisture, which the wood acquires in certain circumstances, and is deprived of in others. It is hardly necessary to mention, that the solids of the preceding table contract their dimensions by cooling, as much as they are expanded by heating; thus, for instance, if a yard's length of any particular metallic body, by being heated 100 degrees above the actual temperature of the atmosphere, be lengthened one-fiftieth part of an inch; afterwards, when cooled down to the temperature of the

atmosphere, it will be found to have lost exactly that fiftieth part of an inch which it had acquired by heating.

From the experiments hitherto made on the expansions of solids by heat, no correspondence has been observed between the expansions and the quantities of caloric they are capable of absorbing. The fusibility of metals seems to coincide with the dilatations; platina, the least fusible of the metals, dilates the least; lead dilates most; and the most fusible glass is also the most dilatable. We may therefore conclude with M. Berthollet, that bodies are so much the more expansible, the less caloric they require, to change their constitution from solid to liquid, and from liquid to gases or vapours.

There is a substance which expands when heated, but does not contract when cooled; and of this singular property Mr. Wedgwood availed himself for the construction of his ingenious thermometer for measuring the highest degrees of heat; viz., those degrees which exceed the scale of the mercurial thermometer. The substance alluded to is the argillaceous earth or clay, and it appears that the above-mentioned property belongs, more or less, to argillaceous bodies of every kind. This property may at first sight appear to be an unaccountable exception from the general law: the difficulty, however, will vanish, if it be considered that bodies of the argillaceous genus contain a considerable quantity of water, and that the contraction of these bodies, when exposed to the action of a strong fire, is in a great measure due to the escape of the water, and hence they do not contract by subsequent cooling.

EXPERIENCE, knowledge derived from trials, long use, practice, or a series of observations. Experience consists in the ideas suggested by what we have seen, read, or done: we reflect on these things, and the judgment forms for itself a rule or standard, which standard is experience.

Authors make three kinds of experience: the first is the simple uses of the external senses, whereby we perceive the phenomena of natural things, without any direct attention thereto, or making any application thereof.

The second is, when we premeditatedly and designedly make trials of various things, or observe those done by others, attending closely to all effects and circumstances.

The third is that preceded by an apprehension of an event, and determines whether the apprehension were true or false; the two latter kinds, especially the third, are of great service in philosophy.

EXPERIMENT, (from the Latin *experimentum,*) a trial, an act, or operation designed to discover some unknown truth, principle, or effect, or to establish it when discovered. In philosophy, it means the result of certain applications, dispositions, or combinations, of natural bodies, made with some particular view. The history of physical science from the commencement of the present century, strikingly demonstrates how powerful an instrument experiment is in the discovery of facts. Experiments are said to be mechanical, or chemical, or electrical, or magnetical, &c., according to the subject to which they more immediately belong. The object of making experiments is to ascertain either certain causes or certain phenomena; and for the proper attainment of these objects, care must be had to institute experiments that admit of no equivocal result, and so as to answer the purpose in the quickest and most direct way. The main object, however, of the inquiry can seldom be determined by a single decisive experiment; hence, in most cases, it becomes necessary to divide the question into parts, and to ascertain each part separately by one or more appropriate experiments. When the experiment is so prescribed, as to decide the question without any possible doubt or equivocation, it has in that case frequently been called *experimentum crucis;* a *crucial experiment,* meaning a capital or decisive experiment; such as supersedes the necessity of instituting more experiments for the same purpose. The origin of the expression *experimentum crucis* has by some been derived from its being a kind of torture, whereby the nature of the question is, as it were, extorted by force. It has been also attributed, by others, though with less apparent probability, to the guide or instruction which it affords, like that of a direction-post, which is shaped somewhat like a cross.

It is not practicable to give any instructions for the right performance of experiments in general; for not only every subject, but every particular question belonging to any subject, must be determined by a particular mode of investigation. The experimenter can only be instructed by practice. The nature of the subject, a strict attention to every apparent circumstance, an accurate statement of particulars, and an unprejudiced mode of reasoning, will easily suggest a proper train of experiments which the subject in question may admit of. It deserves to be remarked, that though in the investigation of any subject, the philosopher proposes a certain order of investigation, (and it is always proper to propose to oneself some such plan or train of experiments;) yet it is but seldom that the proposed plan can, or deserves to be, strictly executed; for the result of the first or second experiment frequently points out a new tract, or a more promising road; in consequence of which, new and different trials must be instituted; it is in the ready adoption of such plans as may be best suited to the last indications, that the genius of the philosopher is rendered conspicuous.

Such mode may suffice for the determination of any doubtful point; but when a discovery has been made, and is to be explained to other persons, then it is of use to show the same result by different experiments; for it is not only a satisfaction to have several concurring proofs of the same proposition; but it is also rendered intelligible to a greater number of readers or hearers; it being seldom the case, that the same experiment conveys an equal degree of conviction and satisfaction to the mind of everybody.

EXPERIMENTAL PHILOSOPHY. Philosophy, from the Greek *philosophia* (φιλοσοφια,) literally signifies "love of wisdom or knowledge," and a philosopher, (φιλοσοφος,) is a lover of wisdom. Pythagoras is said to have been the first person who called himself philosopher, from which appellation the word philosophy was derived, meaning the love of general knowledge. The terms philosophy, philosophical, philosopher, are often used in our language apparently with no great precision, though it is not difficult to deduce from the use of these terms the general meaning or notion which is attached to them. We speak of the philosophy of the human mind, as being, of all philosophies, that to which the name philosophy is particularly appropriated; and so also, by using qualifying terms, we speak of natural philosophy, experimental philosophy, &c.

If this knowledge or philosophy relate to the manners, the duties, or the conduct of human beings, considered in a rational and social light, it is called *moral* philosophy; if to the phenomena of natural bodies—*natural* philosophy. Experimental philosophy, as will be shown hereafter, may be defined as the philosophy of *proof,* in contradistinction to the philosophy of opinion, to the manners, the duties, and the conduct of human beings, considered in a rational and social light, or to the phenomena of natural bodies, so it has been called either *moral philosophy* or *natural philosophy.*

The philosophers of the primitive ages, among the Greeks, Romans, &c., in explanation of the phenomena of nature,

such as the motions of the celestial bodies, the rain, snow, frost, thunder and lightning, the rainbow, the combustion of fuel, the production of animals and vegetables, and so forth, generally offered the inadequate suggestions of their imaginations, which, though mostly unintelligible, and frequently in the greatest degree absurd, were nevertheless received with deference by their scholars, and were propagated with fidelity and diligence from one generation to another. Their acquiescence rested merely on the authority of the teacher. That these explanations were generally inadequate and absurd, is easily evinced by observing, that different contemporary philosophers entertained and taught opinions diametrically opposite to each other, though they related to the very same question; and that subsequent philosophers have, by actual observations, and unerring demonstrations, shown their fallacy. It may amuse an inquisitive mind to observe, that whilst the exertions of the early mathematicians, whose productions have obtained the admiration of subsequent generations, were strictly rational and correct, the investigations of their contemporary philosophers were conducted in a manner altogether slovenly and superficial. This method of philosophizing prevailed for a very long period, and several centuries elapsed, during which the knowledge of nature made no progress deserving of notice, excepting a few rare and accidental discoveries.

The 15th century, which was productive of the greatest events and the most consequential discoveries that history can record, seems to have given a new turn to the subject of natural philosophy. The old tenets began to be doubted, and the energies of the human mind began to manifest their unfettered powers. In the next century, the incoherent dogmas of the preceding ages were freely combated; the authority of names and sects was disregarded, and, in lieu of opinions, the explanation of natural phenomena was referred to the evidence of actual experiments. Then was introduced the appellation of *experimental philosophy*, by which is meant, the knowledge of natural powers and natural effects acquired by means of experiments or trials. The least reflection readily showed the superiority of this new method of philosophizing; but, independent of any other consideration, its establishment is principally due to the success with which it was attended, and which exceeded even the most sanguine expectations of its first promoters. No sooner was it adopted, than discoveries of importance were made, old-established errors were detected, and the subject of philosophy assumed an entirely new aspect.

It is undoubtedly true, that in this mode of investigation the experiments must be preceded by hypothesis, or supposition; for a man cannot begin to make experiments without the previous formation of a certain plan; but then the plan, the supposition, or the hypothesis, goes no farther than to propose something, the confirmation or refutation of which is referred to the result of experiments, assisted by mathematical calculation. In the 13th century, the necessary preliminaries for the improvement of natural knowledge began to be made; viz., collections of what then prevailed under the denomination of scientific knowledge, natural knowledge, secrets of nature, and the like; and the farrago of truths, errors, inconsistencies, doubts, and perplexities, which these works contain, is strange indeed. Among the few who effectually began to work in the experimental mode of investigation, during that century, Friar Bacon held the most distinguished place. His desire of information was great; his views extensive; his mind clear and capacious; and he is said to have spent about £2,000 (a sum very considerable at that time) in the performance of his numerous philosophical experiments. Baptista Porta also distinguished himself for similar pursuits in Italy. This inquisitive person lived at Naples, and about the year 1560 formed a society of scientific persons, who met in his own house. The great Galileo, who was born in Italy, in the year 1564, became famous as a philosopher and a mathematician, towards the latter end of that century and the beginning of the next. His genius, superior to the prejudices of the times, investigated and established several leading propositions in natural philosophy; and his success, his example, and his precepts disseminated a universal ardour for the true mode of investigating the powers and the effects of natural bodies. His successor, Torricelli, was not unworthy of a most distinguished rank amongst the philosophers of the age; and the Torricellian tube, or the barometer, is a magnificent monument of his experimental inquiries.

In England, as we have already mentioned, Friar Bacon was the first promoter of true knowledge; but a great part of the work of philosophical reformation was accomplished by another inquiring genius of the same name. Francis Bacon, lord-chancellor of England, gave a fresh and vigorous impulse to the progress of experimental inquiry. He recorded a vast number of facts, proposed and executed a great many experiments, and nothing that related to nature seemed to be below his notice.

These early reformers of philosophy, besides other obvious difficulties, were obliged to struggle against, and the success of their labours was much impeded by, the erroneous notions which then prevailed, and which had been long rooted in the minds even of the most able persons then living. Galileo was oppressed by the ignorance and prejudices of the clergy. Crichton, who flourished about the latter end of the 16th century, wrote an able book expressly against the vain philosophy of Aristotle, which had long been read in the schools. The two Bacons, and other able writers, frequently allude to, and strenuously endeavour to remove, the absurd and fanciful notions of their contemporaries. In short, the demolition of the old defective fabric, proved nearly as laborious as the erection of the new structure.

The reform which had been begun by the above-mentioned, and other worthy persons, was soon after completed by the extraordinary genius of Newton. This truly great man, like a luminary of the first magnitude, illustrated whatever came within the limits of his notice, and his notice was employed in the greatest and most admired works of the creation. His method was to institute experiments, to examine the phenomena with accuracy, and to ground upon them the strictest mathematical reasoning. The conviction which such a rational method conveyed, and the numerous discoveries with which it was attended, completely exploded the old tenets, and established the only true method of investigating nature.

The progress of experimental philosophy might have been interrupted by the death of a single individual; for it does but seldom occur that genius, health, opulence, and other opportunities, concur in the qualification of an experimental philosopher; but the danger was in great measure averted by the institution of philosophical societies. These societies, by bringing together learned men, and concentrating, as it were, their efforts against the ignorance and prejudice of the age; by uniting the efforts of several ingenious labourers, by furnishing in great measure the means of investigation, by encouraging improvements, and by recording and propagating the results, at length succeeded in establishing the progress of knowledge in a regular and permanent channel.

The first society of the kind which we find recorded, is that which we have already mentioned at the house of Baptista Porta, in Naples, towards the latter end of the

16th century. It was called "Academia Secretorum Naturæ." Next to this, and before the end of the same century, the academy, called the Lyncei, was founded at Rome, and was rendered famous throughout the world, principally by the renown of one of its members, the great Galileo. The Academy del Cimento, and several other associations of scientific persons, were established in the succeeding, viz., the 17th century. Amongst those associations the first rank must be assigned to the Royal Society of London. This most learned and distinguished society had its origin soon after the middle of the 17th century. A few men of learning began to meet at stated times at Wadham college, Oxford; and among those persons were the following conspicuous characters: viz., Dr. Ward, Mr. Robert Boyle, Dr. Wilkins, Sir William Petty, Mr. Matthew Wren, Dr. Wallis, Dr. Goddard, Dr. Willis, Dr. Bathurst, Dr. Christopher Wren, and Mr. Rooke. From Oxford this association transferred its meetings in the year 1658, to Gresham college, in London. There they increased their number; and soon after the restoration of Charles II., the society received a royal charter, which established it in the form that has been continued ever since.

The objects of the universe, or the natural bodies which affect our senses, become known and useful to us by their properties, some of which affect one of our senses, whilst others affect some other sense. Thus we perceive luminous bodies through our eyes, sound through our ears, heat or cold by the touch or feel, &c. Some of these properties are called general, like gravity and extension, because they belong to all bodies; and others, like transparency and fluidity, are called particular, because they belong to certain bodies only. The better we become acquainted with the properties of natural bodies, the more extended the sphere of our powers and of our advantages becomes; and it is for the discovery of these properties, either in simple or in compound bodies, that experimental inquiries are instituted.

In the acquirement of knowledge, the human being has no other assistance besides that of his senses, and of his reasoning faculty. By the first he observes and acquires ideas of self-evident propositions, or properties of natural bodies; such as the human mind cannot dissent from without manifest violence to its perceptions; by the second he is led from one of these evident simple propositions, to another strictly depending upon the first, then to a third strictly depending upon the second, and so on, to the acquisition of some idea more complex, and less apparent at the first annunciation. The constant observation of philosophers, with Sir Isaac Newton at their head, and the dictates of plain reasoning, have furnished certain axioms and certain rules of philosophizing, the propriety of which is too evident to be objected to.

The axioms of philosophy, or the axioms which have been deduced from common and constant experience, are so evident, and so generally known, that it will be sufficient to mention a few of them only.

1. Nothing has no property ; hence

2. No substance, or nothing, can be produced from nothing.

3. Matter cannot be annihilated, or reduced to nothing.

The propriety of the last axiom may perhaps not be readily admitted by certain persons; observing that a great many things appear to be utterly destroyed by the action of fire; also that water may be caused to disappear by means of evaporation; and so forth. But it must be observed, that in these cases the substances are not annihilated; they are only dispersed, or removed from one place to another, and by being divided into particles very minute, they elude our senses, and escape our immediate notice. Thus, when a piece of wood is placed upon the fire, the greatest part of it disappears, and a few ashes only remain, the weight and bulk of which do not amount to the hundredth-part of the weight and bulk of the original piece of wood. In this case the piece of wood is divided into its constituent principles, which the action of the fire drives different ways. The fluid part, for instance, becomes steam, the light coaly part either adheres to the chimney, or is dispersed through the air, &c., so that if, after the combustion, the scattered materials were collected, (which may in a great measure be accomplished,) the sum of their weights would equal the weight of the original piece of wood.

4. Every effect has, or is produced by, an adequate cause, and is proportionate to it.

It may, in general, be observed, with respect to these axioms, that we only mean to assert what has been constantly shown, and confirmed by experience, and is not contradicted, either by reasoning, or by any known experiment. But we do not mean to assert that they are as evident as the axioms of geometry; nor do we in the least presume to prescribe limits to the agency of the Almighty Creator of every thing, whose power and whose ends are too far removed from the reach of our finite understandings.

Having thus stated the principal axioms of philosophy, it is in the next place necessary to mention the rules of philosophizing, which have been formed, after mature consideration, for the purpose of preventing errors as much as possible, and of leading the student of nature, along the shortest and safest path, to the attainment of true and useful knowledge. These rules may be reduced to four, viz.

1. We are to admit no more causes of natural things, than such as are both true, and sufficient to explain the appearances.

2. Therefore, to the same natural effects we must, as far as possible, assign the same causes.

3. Such qualities of bodies as are not capable of increase, or of decrease, and which are found to belong to all bodies within the reach of our experience, are to be esteemed the universal qualities of all bodies whatsoever.

4. In experimental philosophy we are to look upon propositions collected by general induction from phenomena, as accurately, or very nearly true, notwithstanding any contrary hypothesis that may be imagined, till such time as other phenomena occur, by which they may either be corrected, or may be shown to be liable to exceptions.

With respect to the degree of evidence which ought to be expected in natural philosophy, it is proper to remark, that physical matters are not, in general, capable of such absolute certainty as the branches of mathematics. The propositions of the latter science are clearly deduced from a set of axioms so very simple and evident, as to convey perfect conviction to the mind; nor can any of them be denied without a manifest absurdity. But in natural philosophy we can only say, that because certain particular effects have been constantly produced under certain circumstances, therefore they will most probably continue to be produced as long as the same circumstances exist; and likewise that they do, in all probability, depend upon those circumstances. And this is what we mean by *laws of nature*, viz., certain effects which are, or have been uniformly, produced by certain causes, as far as our observations reach.

We may, indeed, assume various physical principles, and by reasoning upon them, we may strictly demonstrate the deduction of certain consequences. But as the demonstration goes no farther than to prove, that such consequences must

necessarily follow the principles which have been assumed; the consequences themselves can have no greater degree of certainty than the principles are possessed of; so that they are true, or false, or probable, according as the principles upon which they depend are true, or false, or probable.

The foundations of experimental philosophy, as we have already observed, are the properties of natural bodies, viz., of all these bodies, either solid or fluid, which in any way affect any of our senses; and since our senses are affected by the properties of these bodies, viz., by their extension, colour, hardness, transparency, &c., we cannot know any more of these bodies than what is manifested to us by such properties only as we are able to perceive. Were we furnished with other senses, doubtless we might discover other properties which would make us more intimately acquainted with the nature of such bodies.

Human art has not been able to discover more senses than those which everybody knows; but it has, in great measure, improved some of those which we possess, and this alone is sufficient to point out the limited nature of our perceptions. Thus, for instance, the discovery of the microscope and the telescope have shown us wonders, of which our forefathers were utterly ignorant; and the number and variety of these wonders have increased, in proportion as the above-mentioned instruments have been improved. The improvements of these instruments have been suggested by the discoveries that have been made respecting the refrangibility of light, and the properties of transparent bodies, and these have been made in consequence of the innumerable experiments that have been instituted by various intelligent persons. Thus it appears, that by means of trials and observations, new facts are ascertained, which, besides their being immediately useful to the human species, furnish, at the same time, the means of making farther discoveries; and the treasures of the natural world are far, indeed, from a state of exhaustion. Hence the improvements and the discoveries of experimental philosophy proceed in a kind of increasing geometrical progression; unless they are impeded by some extraordinary occurrence.

In contemplating the intimate nature of natural bodies, when our mind goes beyond the bounds of our senses, (and our senses, even with the assistance of instruments and reasoning, are only capable of perceiving a few properties of those bodies;) we wander in the boundless field of probability and conjecture. Two principal hypotheses have been entertained with respect to the primitive component particles of bodies. One is, that the particles of each peculiar species of bodies are different from the particles of another species of bodies. Thus the primitive particles of gold are supposed to be different from the particles of calcareous earth, different from the particles of water, &c. The other hypothesis is, that there is one kind of primitive, or original particles of matter, and that from the different arrangement of those ultimate particles, the various bodies arise. Experience shows, that certain bodies, which at first sight appear to be absolutely different from each other, are, upon farther examination, exactly of the same nature. On the other hand, a vast number of bodies are so distinct from each other, that no art has been able to form one of them from the particles of the other; thus gold cannot be converted into a diamond, iron cannot be converted into lead, &c. The former of these observations seems to favour the second hypothesis; the latter seems to favour the first hypothesis; but it is not in our power to determine the real state of the matter.

With respect to the number of bodies, which, by our not being able to change one of them into the other, are called elementary, or primitive and distinct; it may be remarked, that new bodies are frequently discovered in proportion as new instruments, and the improvements of science in general, furnish us with the means of discriminating them from others. We are thus naturally led to conclude, that in all probability there exists a vast number of other bodies, of which we at present have not the least suspicion. Some of these may perhaps be discovered hereafter, others may remain utterly unknown to the human species for ever.

The properties of natural bodies, which are the objects of research to the experimental philosopher, are either general, or particular. The general properties, which belong to all kinds of bodies, are, as far as we know, not more than six; viz., extension, divisibility, impenetrability, mobility, vis inertiæ, or passiveness, and gravitation. We have said that these are the general properties as far as we know, because matter in general may possess other properties with which we are yet unacquainted. And the same observation may be made with respect to the universality of these properties: for they are said to be general, because nobody was ever found which wanted any one of them. But mankind are not acquainted with all the bodies of the universe, and many which are known to exist, cannot be subjected to experiments.

The peculiar properties, viz., those which belong to certain bodies only, and not to others, are density, rarity, hardness, softness, fluidity, rigidity, flexibility, elasticity, opacity, transparency, the properties of light, the properties of heat, the properties of electricity, the properties of magnetism, and three other kinds of attraction, (independent of gravitation, of electricity and of magnetism,) viz., the attraction of aggregation, which the homogeneous parts of matter have towards each other, or by which they adhere together; and such is the power by which two small drops of mercury, when placed contiguous to each other, rush, as it were, into each other, and form a single drop; the attraction of cohesion, or that power by which the heterogeneous particles of bodies adhere to each other without any change of their natural properties, such as the adhesion of water to glass, of oil to iron, &c.; and the attraction of composition, or of affinity, which is the tendency that the parts of heterogeneous bodies have towards each other, by which they combine, and form a body, differing more or less from any of its components.

It is to be remarked, that of all these properties we know their existence only, and some of the laws under which they act; but we are otherwise utterly ignorant of their nature and dependence.

The investigation of some of the above-mentioned properties, whether general or particular, has been carried much farther than the investigation of other properties. The results of these investigations have likewise been various, both in point of extent and of application. Some of them are so very extensive and so useful, as to form the foundations of very important branches of science, or of art, under peculiar appellations. Thus, upon the mobility, and the vis inertiæ of bodies, the doctrine of motion, or dynamics, is grounded, which comprehends mechanics, hydrostatics, or the mechanical properties of fluids, pneumatics, &c. Transparency and the properties of light form the important foundation of optics. The attraction of affinity is the foundation of chemistry, as well as of various arts; and so forth.

The phenomena of the universe, are the appearances which take place in consequence of the above-mentioned properties of natural bodies, together (respecting some of them at least) with some original impulse. The phenomena which take place amongst the luminous celestial bodies, properly so called, such as the stars, the planets, &c., are examined by

a particular science, called astronomy; the meteors, or the phenomena which take place within the limits of the terrestrial atmosphere, such as shooting stars, northern lights, halos, rain, fogs, hail, winds, &c., form the subject of meteorology.

EXPLOSION, in natural philosophy, a sudden and violent expansion of an aërial or other elastic fluid, by which it instantly throws off any obstacle that may be in the way. It differs from expansion, properly so called, in this, that the latter is a gradual and continued power, whereas the former is always sudden, and of only momentary duration.

Explosion, in military engineering. It is a matter of great moment, so to load, and indeed to construct a mine, that it may explode with the greatest precision, and with the maximum effect. Numerous theories have been given upon this subject, but it would be out of place to notice the whole of what appertains thereto in a work like this.

In commencing operations, it is necessary in the first instance to ascertain, so nearly as may be practicable, what depth, and what weight of soil is to be removed by an explosion. This being done, the mine is formed, by constructing a gallery leading to the chamber in which the powder is to be placed. This must be deposited in a very strong chest, let into a recess, and firmly secured in every part. Now, it being the nature of rarefied air to escape by that part which may be the weakest, it is evident, that if a mine is made under a rampart, so as to be within six feet of the surface, while all the sides are thicker by far than that measurement, the explosion will be directed towards that part which is thinnest, and which, from that circumstance, is called "the line of least resistance."

But, in order to direct the explosion to that part, it will be necessary to consider whether the soil be everywhere alike; for if the superincumbent portion should be part of a large stratified rock, while the sides are of a loose, inadhesive substance, the latter, though measuring more in diameter will give the line of least resistance, which, in such case, would follow the intenacity, and create a false explosion. For it must be recollected that explosions may be lateral as well as vertical.

It was formerly supposed, that the diameter of the *entonnoir*, or explosion, was equal to double the line of least resistance; but we find that six times that line may be exploded, by allowing a load of 300 lbs. of gunpowder, duly concentrated, and fired in the middle of the mass, for every foot of the line of least resistance. We are not to infer from this, that 300 lbs. will be requisite to lift one foot of soil; far from it; for as a cubic foot of excavation will contain only 75 lbs. of powder, the above quantity (300 lbs.) would require a space of exactly four cubic feet; the proportion would therefore be preposterous. But when we calculate upon large masses of soil, such as those prodigious cones thrown out from entonnoirs of great extent, we then find, that, to produce the completest explosion, an immense quantity of powder must be supplied.

It is self-evident, that the power of the powder, according to the above scale, is only computed to that extent which may be necessary towards the ordinary purposes of military devastation; for if we were to contribute, *ad infinitum*, 300lbs. of gunpowder for every foot in the line of least resistance, we should be accumulating power only in arithmetical proportion, while the resistance would be increasing in a geometrical ratio: of course the power must be in a regular state of comparative diminution, in proportion as the line of least resistance is increased; and this must, after a while, occasion the powder to be inert; or, if there should be any explosion, it could only follow the track of the train. Its ignition, to be sure, might be felt partially, like that of a slight earthquake, but no superficial effects would be observable.

It has been already stated, that the powder must be lodged in bulk; and that it should be ignited at the centre. This may, perhaps, appear superfluous; but all military men know, that much powder is blown out of the muzzles of pieces without ever being ignited; and we have a most remarkable fact in modern times, one indeed, which shows, that, unless in bulk, powder is not always sure to be fired *in toto*. The incident alluded to is as follows:—

In the month of March, in the year 1809, a barge was proceeding along the new cut, from Paddington, laden with casks of spirits and barrels of gunpowder. One of the crew, it is supposed, allured by the former, bored a hole for the purpose of drawing off a little wherewith to tipple. Unhappily the action of the gimblet set fire to the contents of that barrel, which the dishonest navigator had mistaken for one of spirits. The barrel exploded, and drove eleven other barrels, filled with gunpowder also, to the distance of near a hundred and fifty yards. It is curious, that although the whole of the powder-barrels were together, indeed in contact, only that in question exploded.

Vauban gives us the following scale for exploding soils of various descriptions. He calculates, or perhaps found from experience, that for a cubic fathom (six feet) of soil, measuring in all 216 solid feet, the following proportions of gunpowder were needful.

	lb.
1. Light earth, mixed with sand	11
2. Common earth	12
3. Strong sand	15
4. Clay, or fat earth	16
5. Old, and good masonry	18
6. Rock	20

In following this calculation, we are to consider the entonnoir to be in diameter equal to only double the line of least resistance; and not according to a maximum explosion.

A new substance, gun-cotton, which is cotton wool steeped in nitric or nitro-sulphuric acid, and dried, by which it becomes explosive, has been lately introduced as a substitute for gunpowder in blasting. It is not yet sufficiently understood to have come into extensive use.

EXPONENT, in algebra, is a number placed over any power or involved quantity, to show to what height the root is raised; thus 2 is the exponent of x^2 and 4 is the exponent of x^4 or $x\,x\,x\,x$.

EXPONENTIAL CURVES, those curves which partake both of the nature of algebraic and transcendental ones. They are algebraical in their nature, because they consist of a finite number of terms, though these terms themselves are indeterminate, and they are in some measure transcendental, because they cannot be algebraically constructed.

EXPOSURE, the act of exposing or laying open to view; as we say a building, a garden, or a wall, had a northern or a southern *exposure*, and we speak of its exposure or exposition to a free current of air, or to the access of light.

EXTEND, to stretch in any direction, to continue in length as a line, to spread in breadth.

EXTENSION, in philosophy, one of the general and essential properties of matter; the extension of a body being the quantity of space which the body occupies, the extremities of which limit or circumscribe the matter of that body. It is otherwise called the *magnitude*, or *size*, or *bulk* of a body.

A quantity of matter may be very small, or so as to elude the perception of our senses, such as a particle of air, a particle

of water, &c.: yet some extension it must have, and it is by the comparison of this extension, that one body is said to be larger than, equal to, or smaller than, another body. The measurement of a body consists in the comparison of the extension of that body with some determinate extension, which is assumed as a standard, such as an inch, a foot, a yard, a mile; hence it is said, that a body is a foot long, or three inches long, &c.

The extension of a body is measured three different ways; or a body is said to have length, breadth, and thickness. Thus an ordinary sheet of writing paper is about 16 inches long, about 14 inches broad, and nearly one hundredth part of an inch thick. Either of these dimensions might be called the length, or the breadth, or the thickness; but, by general custom, the greatest extension is called the length, the next is called the breadth, and the shortest is called the thickness. The outside of a body, its boundary, or that which lies contiguous to other bodies that are next to it, is called the *surface* of that body, and this surface has two dimensions only, viz., length and breadth; but it has no thickness, for if it had, it would not be the outside of the body; yet a surface by itself cannot exist. In mathematics, however, surfaces are mentioned, and are reasoned upon, abstractedly from matter. But in these cases the surfaces exist in the imagination only, and even then our ideas have a reference to body, for our senses cannot perceive a surface without a body.

As a surface is the outside or boundary of a body, so a *line* is the boundary of a finite surface. Suppose, for instance, that a surface is divided into two parts, the common boundary of the two parts is called a *line;* this has one extension only, viz., it has length.

The beginning or the end of a line, or the intersection of two lines which cross each other, is called a *point*, and this has no dimensions; or, according to the mathematical definition, a point is that which has no parts or magnitude, its use frequently is to mark a situation only as a point upon a surface by the intersection of two lines, &c. Thus, if you divide a line into two parts, the division or boundary between the two parts is a point.

Our senses are only capable of perceiving bodies which have three dimensions; or rather the surfaces of bodies, which surfaces have two dimensions, but a surface cannot be represented nor perceived without a body, and of course neither a line nor a point can be perceived without a body. In the study of geometry, and in a variety of other branches, surfaces, lines, and points are represented upon paper, or upon something else; but in those cases, the paper, or that something else, is the body whose surface we perceive, and the surface of a particular figure is circumscribed, not by real lines, but by a narrow slip of surface, which is sufficient to direct our reasoning with respect to the geometrical properties of lines and surfaces. Thus also, when points are represented by themselves, the marks are not real points, but very small portions of the surface of a body.

There is a case in which extension is often said to be perceived without the existence of a body, and this is the extension between two bodies. But, upon consideration, it will easily be comprehended, that we may perceive the two bodies, and that they are separate from each other; but we cannot perceive anything positive between them. So that in this case the word extension is used in a figurative manner, as if some other body existed between the two bodies.

The particular extension, whether under the name of inch, foot, yard, metre, league, &c., with which other extensions are compared, or by which they are measured, is established only by the common consent or agreement of persons of a certain nation, or profession, and used as standard measure by them only. Hence, the measures of different nations, though sometimes they have the same name, differ considerably from each other. Great endeavours have been made by divers ingenious persons, at different times, for the purpose of determining an unalterable universal standard of measures; those endeavours, and the results with which they have been attended, will be found described under the article STANDARD *of Measures.*

Extension is usually described as consisting in the situation of parts beyond parts; but to this definition some authors object, maintaining, that we can conceive absolute extension without any relation to parts.

If a man consider the distance between two bodies abstractedly, and without any regard to bodies which may fill that interval, it is called space; and when he considers the distance between the extremes of a solid body, it is called extension.

Extension is frequently confounded with quantity and magnitude; and, for what we can perceive, without much harm, the thing signified by them all appearing to be the same; unless we admit a distinction made by some authors, that the extension of a body is something more absolute, and its quantity and magnitude more respective, or implying a nearer relation to much and little. The infinite divisibility of extension has been a famous question in all ages. It is not easy to reconcile the doctrine of mathematicians on this head with the tenets of some philosophers. Those who hold that all extension and magnitude are compounded of certain *minima sensibilia;* and that a line, for instance, cannot increase or decrease, but by certain invisible increments or decrements only, must, consistently with themselves, affirm, that all lines are commensurable to each other. But this is contrary to the tenth book of Euclid, who demonstrates that the diagonal of a square is incommensurable to its side. And further, if all lines were composed of certain indivisible elements, it is plain one of those elements must be the common measure of the diagonal and the side.

Bishop Berkeley observes, that the infinite divisibility of finite extension, though it is not expressly laid down, either as an axiom or theorem in the elements of geometry, is yet throughout the same everywhere supposed, and thought to have so inseparable and essential a connection with the principles and demonstrations in geometry, that mathematicians never admit it into doubt, or make the least question of it. And as this notion is the source from whence do spring all those amusing geometrical paradoxes, which have such a direct repugnancy to the plain common sense of mankind; so it is the principal occasion of all that nice and extreme subtilty which renders the study of mathematics so difficult and tedious. Hence, says he, if we can make it appear, that no finite extension contains innumerable parts, or is infinitely divisible, it follows, that we shall at once clear the science of geometry from a great number of difficulties and contradictions which have ever been esteemed a reproach to human reason, and withal, make the attainment thereof a business of much less time and pains than it hitherto hath been.

Every particular finite extension, which may possibly be the object of our thought, is an idea existing only in the mind, and consequently each part thereof must be perceived. If therefore, says this author, I cannot perceive innumerable parts in any finite extension that I consider, it is certain they are not contained in it; but it is evident, that I cannot distinguish innumerable parts in any particular line, surface, or solid, which I either perceive by sense, or figure to myself in my mind; wherefore, I conclude they are not contained

in it. Nothing can be plainer to me than that the extensions I have in view are no other than my own ideas; and it is no less plain, that I cannot resolve any one of my ideas into an infinite number of other ideas; that is, that they are not infinitely divisible. If by an infinite extension be meant something distinct from a finite idea, I declare I do not know what that is, and so cannot affirm or deny anything of it. But if the terms extension, parts, and the like, are taken in any sense conceivable; that is, for ideas; then to say a finite quantity or extension consists of parts infinite in number, is so manifest a contradiction, that every one at first sight acknowledges it to be so.

On the other hand, it is observed by an eminent mathematician, that geometricians are under no necessity of supposing that a finite quantity of extension consists of parts infinite in number, or that there are any more parts in a given magnitude than they can conceive or express: it is sufficient that it may be conceived to be divided into a number of parts equal to any given or proposed number; and this is all that is supposed in strict geometry concerning the divisibility of magnitude. It is true, that the number of parts into which a given magnitude may be conceived to be divided, is not to be fixed or limited because no given number is so great, but a greater than it may be conceived and assigned: but there is not therefore any necessity for supposing that number infinite; and if some may have drawn very abstruse consequences from such suppositions they are not to be imputed to geometry. Geometricians are under no necessity of supposing a given magnitude to be divided into an infinite number of parts, or to be made up of infinitesimals; nevertheless they cannot so well avoid supposing it to be divided into a greater number of parts than may be distinguished in it by sense in any particular determinate circumstance. But they find no difficulty in conceiving this; and such a supposition does not appear to be repugnant to the common sense of mankind, but, on the contrary, to be most agreeable to it, and to be illustrated by common observation. It would seem very unaccountable not to allow them to conceive a given line, of an inch in length for example, viewed at the distance of 10 feet, to be divided into more parts than are discerned in it at that distance: since by bringing it nearer, a greater number of parts is actually perceived in it. Nor is it easy to limit the number of parts that may be perceived in it when it is brought near to the eye, and is seen through a little hole in a thin plate; or, when by any other contrivance it is rendered distinct at small distances from the eye. If we conceive a given line, that is the object of sight, to be divided into more parts than we perceive in it, it would seem that no good reason can be assigned why we may not conceive tangible magnitude to be divided into more parts than are perceived in it by the touch; or a line of any kind to be divided into any given number of parts, whether so many parts be actually distinguished by sense or not. In applying the reasonings and demonstrations of geometricians on this subject, it ought to be remembered, that a surface is not considered by them as a body of the least sensible magnitude, but as the termination or boundary of a body; a line is not considered as a surface of the least sensible breadth, but as the termination or limit of a surface; nor is a point considered as the least sensible line, or a moment as the least perceptible time; but a point as a termination of a line, and a moment as a termination of a limit of time. In this sense they conceive clearly what a surface, line, point, and a moment of time, is; and the postulata of Euclid being allowed and applied in this sense, the proofs by which it is shown, that a given magnitude may be conceived to be divided into any given number of parts, appear satisfactory; and if we avoid supposing the parts of a given magnitude to be infinitely small, or to be infinite in number, this seems to be all that the most scrupulous can require.

Dr. Reid, in his "Inquiry into the Human Mind, on the Principles of Common Sense," considers that it is absurd to deduce from sensation the first origin of our notions of external existence, of space, motion, and extension, and all the primary qualities of bodies; they have, he says, no resemblance to any sensation, or to any operation of our minds, and therefore they cannot be ideas either of sensation or reflection; nor can he conceive how extension, or any image of extension, can be in an unextended and indivisible subject like the human mind.

EXTERNAL, or Exterior, (from the Latin *externus*, outward,) a term of relation, applied to whatever is on the surface or outside of a body, and opposed to *internal* or *interior*.

External or Exterior Angles. *See* Angles.

EXTRADOS, (from the Latin, *extrà*, outer, and *dorsus*, the back,) the external surface of a vault. The surface on the upper side of the voussoirs of an arch. *See* Arch, Bridge.

EXTREME, (from the Latin *extremus*, utmost,) whatever finishes or terminates on one side of a thing. The extremes of a line are points.

EYE, (from the Saxon,) a circular window in a pediment, attic, the reins of a vault, or the like.

Eye, *Bullock's*, (in French, *uil de bœuf*) a little skylight in the covering or roof, intended to illuminate a granary, &c. It is also applied to the little lanterns in a dome, as at St. Peter's at Rome, which has forty-eight, in three rows.

Eye of a Dome, the aperture at the summit, as that of the Pantheon at Rome, or of St. Paul's, London.

Eye of a Volute, the circle at the centre, from the circumference of which the spiral line commences. *See* Spiral and Volute.

Eye, in perspective, the point where the organ of vision is fixed, in order to view the object.

Eye-Brow, the same as Fillet, which see.

F.

FAB

FABER, a workman, the Romans gave this name to artisans or mechanics who worked in hard materials.

FABRIC, (from the Latin, *fabrica*, French *fabrique*, originally the workshop of a mechanic, *a smith's shop or forge*) the structure or construction of anything, particularly a building.

In Italy, the word is applied to any considerable building; in France, it rather signifies the manner of building.

FAC

FAÇADE, or Face, (from the Latin *facies*, the front) the face or front view of an edifice; that portion of the surface of a building which presents itself to the eye. Façade was used originally to denote the principal front of a building; and the term Facciata, used by the Italians, is, for the most part, applied to such fronts as have a principal entrance. The word is now generally made use of when speaking of archi-

tectural buildings, as the façade of the Louvre, or the façade of St. Peter's, &c.

FACE, or FACIA (from the Latin) a vertical member in the combination of mouldings, having a very small projection, but considerable breadth; such as the bands of an architrave. *See* FASCIA.

FACE MOULD, in the preparation of the hand-rail of a stair, a mould for drawing the proper figure on both sides of the plank; so that when cut by a saw held at a certain inclination, the two surfaces of the rail-piece will be every where perpendicular to the plan, when laid in their intended position.

FACE OF A STONE, the surface intended for the front of the work. The face is easily known when the stone is scalped, as being opposite to the back, which is rough as it comes from the quarry. The surface of the splitting grain ought always to be perpendicular to the face.

FACET, or FACETTE, a flat projection between the flutings of columns.

FACIA. *See* FASCIA.

FACING, in engineering, a small thickness of common earth, soil, or stuff of a canal, laid in front of the side lining or puddle on the sloping sides. It is of use to hold up the puddle while working and chopping, in the act of puddling, and afterwards to guard the puddle from being penetrated by the hitchers and poles used by the barge-men.

FACING, a thin covering of a better material, to improve the appearance, or add to the strength of anything. Thus the thin covering of polished stone, or the stratum of plaster, or cement on a brick or rough stone wall is called a facing.

FACING, FAÇADE, or REVETEMENT, in fortification, the portion of masonry, or rather building, given to ramparts, with a view to prevent the soil of which they are composed from crumbling or giving way. When the wall is of masonry, it should be 5 feet thick at the top, with tresses, called *counterforts*, at about 15 feet apart, to strengthen the facing. In order to prevent escalade, the facing is generally made full 27 feet high, from the bottom of the ditch to the cordon. When the facing is carried up as high as the soles of the embrasures, it is called a *whole revetement;* but when confined to the ditch only, it is called a *half revetement.* These must depend upon the nature of the soil, the facility of obtaining materials, the time that can be allowed, the importance of the post, &c. When difficulties occur, as also in temporary works, the facings are made with turf, in which case they are said to be *gazoned.* For field-works, and particularly in the conducting of sieges, fascines or faggots, made of various materials, are very generally employed, and answer the intention.

FACINGS, in joinery, all those fixed parts of wood-work which cover the rough work of the interior of walls, and present themselves to the eye in the completion.

FACTABLING. *See* COPING.

FAIR CURVE, in ship-building, a winding line, used in delineating ships, whose shape is varied according to the part of the ship which it is intended to describe.

FAHRENHEIT, the presumed inventor of the thermometer which bears his name. It is quite unknown on what grounds he made choice of the fixed points on his scale, or of the number of graduations between them, but it is supposed that one of the fixed points was that of boiling-water, and that the other, the *zero* of the scale, was that at which the top of the column stood, when the instrument was exposed to an intense cold in Iceland, in 1709. The extent of the scale between this last point, and that of boiling-water, is divided into 212 parts, and the point of freezing water is at the thirty-second division from the zero point.

FALD-STOOL, a portable folding seat of wood or metal, often of elaborate workmanship, and covered with rich hangings of silk or other material. The term is applied to the Litany stool, or low desk, used in churches, from which the Litany is said. Its position is in the middle of the choir, near the steps of the altar.

FALL. *See* MEASURE, and WEIGHTS AND MEASURES.

FALLING MOULDS, the two moulds which are applied to the vertical sides of the rail-piece, one to the convex, the other to the concave side, in order to form the back and under surface of the rail, and finish the squaring.

FALLING SLUICES, in engineering, gates contrived to fall down of themselves, and enlarge the water-way, on the increase of a flood, in a mill-dam, or the pond of a river navigation.

FALSE ROOF, of a house, that part between the upper room and the covering.

FANE. *See* VANE.

FAN-SHAPED WINDOW, a window consisting of rather more than a semi-circle, the circumference of which is cut out in circular notches.

FAN-TRACERY VAULTING, a mode of vaulting very much in use in late Perpendicular buildings. In this vaulting, all the ribs and principal lines diverge equally in every direction from a point at the springing of the vault, every rib preserving the same curvature; the spaces between the ribs are piled up with panelling and rich tracery. The name is applied from the similarity of this kind of roof to an open fan. Beautiful specimens exist at King's College Chapel, Cambridge; St. George's, Windsor; and Henry VII.'s Chapel, Westminster; also in many smaller erections, such as chantries, tombs, &c.

FANUM, among the Romans, a temple consecrated to some deity. The deified mortals, among the heathens, had likewise their *fana:* even the great philosopher, Cicero, erected one to his daughter Tullia.

FANUM JOVIS, a temple of Jupiter, in Asia Minor, near the Thracian Bosphorus and the Syrnæan promontory.

FARM. It is not within our province to enter on the subject of the mangement of a farm; but as the construction of the buildings belonging to one is frequently entrusted to architects and surveyors, especially in a country practice, it is desirable to offer a few observations respecting farm-buildings. The directions of Vitruvius are as follow:—"The magnitude of the buildings must depend wholly on the quantity of land attached to them, and upon its produce. The number of courts and their dimensions must be proportioned to the herds of cattle and quantity of oxen employed. The kitchen should be situated in the warmest part of the court, and the stable for the oxen contiguous to it; the stalls should be made to face the hearth and the east, because when oxen are constantly exposed to light and heat they become smooth-coated. No husbandman, however ignorant, will suffer cattle to face any other quarter of the heavens than the east. The width of the stables ought not to be less than 10, nor more than 15 feet, their length proportioned to the number of yokes, each of which should occupy an extent of 17 feet. The scalding-rooms should adjoin the kitchen, in order that the operation of cleansing the utensils may be performed upon the spot. The courts for sheep, &c., should be so spacious as to allow not less than 4½, nor more than 6 feet, to each animal.

"The granaries should be above ground, and made to front either the north or the north-east, in order that the grain may not be liable to ferment; but, on the contrary, by exposure to a cold atmosphere, may be preserved a long time: all other prospects encourage the propagation of worms

and insects destructive to grain. The stables should be built in the warmest part of the villa, most distant from the hearth; because when horses are stalled near fire they become rough-coated. It is likewise expedient to have stalls for oxen at a distance from the kitchen, in the open air; these should be placed so as to front the east, because if they are led there to be fed in winter, when the sky is unclouded, they will improve in appearance. The barns, the hay-yards, the corn-chambers, and the mills, ought to be without the walls, so that the farm may be less liable to accidents by fire." An excellent work on farm-buildings has been written by Mr. G. A. Dean, of Stratford.

FASCIA, FACIO, or FACE (from the Latin, *facia*) a vertical member, of considerable height, but with a small projection, used in architraves and pedestals. In the Grecian Doric, the architrave under the band consists only of a single face; as does also the Ionic on the temple of the Illysus, in Attica. The Ionic on the temple of Erechtheus, at Athens, has three fasciæ; as have several celebrated examples of the latter order. Vitruvius allows only a single face to the Tuscan and Doric orders: that is, he makes it all plain, without any divisions or cantoning into parts or fasciæ.

In brick buildings, the jutting out of the bricks beyond the windows in the several stories, except the highest, are called *fascias* or *fasciæ*. These are sometimes plain, and sometimes moulded; but the moulding is only a sima reversa, or an ogee, with two plain courses of brick over it, then an astragal, and lastly, a boultine.

FASCINE, (from *fascis*, a bundle,) in fortification, a number of small sticks of wood, bound at both ends and in the middle, used in raising batteries, in filling ditches, in strengthening ramparts, and making parapets. Smeaton and other engineers have used wattled wood or hedge-work for groins, &c., to retain the pebbles or beach, and break the waves on the shore.

FASTIGIUM, (Latin, *a top* or *ridge*) the upper or crowning member of a building. The term is also applied to PEDIMENT; which see.

FATHOM (from the Saxon) a long measure of six feet, taken from the extent of both arms, when stretched in a right line. It is used in measuring the depth of water, quarries, wells, and pits. It is also always used in nautical matters, as in heaving the lead, &c.

FAUX, a narrow passage used as a means of communication between the atrium and peristylium, the two principal divisions of a Roman house.

FAVISSA (Latin) a hole, pit, or vault under ground, to keep something of great value.

FEATHER-EDGED BOARDS, those of a trapezoidal section; that is, thicker on one edge than on the other: they are used in the facing of wooden walls, and sometimes for the covering of an inclined roof, by lapping the thick edge of the upper board upon the thin edge of the lower one: boards of this description are also employed in fence walls, but are then most frequently placed vertically.

FEATHER-EDGED COPING. *See* COPING.

FEATHERING, an ornament in use in Early English, and the later periods of Gothic architecture, consisting of an arrangement of small arcs in juxtaposition, and forming, at their intersection, projecting points or cusps. Sometimes we find a second and even a third series of these ornaments, one within the other. *See* FOLIATION.

FEEDER, in engineering, a cut or channel, sometimes called a *carriage* or *catch-drain*, by which a stream or supply of water is brought into a canal: sometimes the stream of water itself thus supplied, is called a *feeder*.

FEEDING-HOUSE, or SHED, a building in a farm, for the purpose of fattening neat cattle. It should have a dry warm situation, capable of free ventilation, and be well supplied with proper conveniences for the reception of food and water.

FELLING, of timber, the cutting of trees close by the root, for the purpose of building: the proper season for this purpose, is about the end of April.

FELT-GRAIN: when a piece of timber is cloven or split towards the centre of the tree, or transversely to the annular rings or plates, that position of splitting is called the *felt-grain;* and the transverse position, or rather that which is in the direction of the annular plates, is called the *quarter grain.*

FELTING, the splitting of timber by the *felt-grain.*

FEMUR, the plane space intervening between the channels in the triglyphs of the Doric order.

FENCE, (from the Latin *defendo*, to defend) any sort of construction for the purpose of enclosing land; as a bank of earth, a ditch, hedge, wall, railing, paling, &c.

FENCE, the guard of a plane, which obliges it to work to a certain horizontal breadth from the arris: all moulding planes, except hollows, rounds, and snipes' bills, have fixed fences, as well as fixed stops; but in fillisters and plows the fences are moveable.

FENESTELLA, a niche on the south side of the altar in churches, in which the piscina and sometimes credence table also is placed. These niches are of various forms and degrees of ornamentation; some of them are very richly finished. In some instances a double niche is found, one for the piscina and the other for the credence table. *See* PISCINA, CREDENCE TABLE, CHANCEL, &c.

FENESTRATION, the arrangement of windows in a building. The term is also used in contradistinction to *columniation*, when speaking of the design and composition of a building generally; the former term being used in reference to an edifice in which windows form the principal feature, the latter to that in which the columnar arrangement is adopted. Buildings in which both windows and columns are employed, are termed *columnar-fenestrated.*

FERETORY, (Latin *fero*, to carry,) a bier, coffin, shrine, or tomb. The term is more properly applied to portable shrines.

FESTOON, a representation in sculpture of bands of flowers, drapery, foliage, &c., looped up or suspended at regular intervals. This decoration was used by the ancients in friezes, &c.

FETCHING THE PUMP, the act of pouring water into the upper part of a pump, to expel the air contained between the lower box, or piston, and the bottom of the pump.

FIGURE (from the Latin *figura*, likeness) in a general sense, the terminating extremes, or surface of a body.

No body can exist without figure, otherwise it would be infinite, and consequently all space would be solid matter.

FIGURE, in geometry, any plane surface comprehended within a certain line or lines.

Figures are either rectilinear, curvilinear, or mixed, according as the perimeter consists of right lines, or curved lines, or both.

The superficial parts of a figure are called its *sides*, or *faces*, and the lowest side its *base;* if the figure be a triangle, the angle opposite the base is called the *vertex*, and the height of the figure is the distance of the vertex from the base.

FIGURE, in architecture and sculpture, representations of things made of solid matter, as statues, &c., thus we say figures of brass, of marble, of stucco, of plaster, &c.

Figures, in architecture, are said to be *detached* when they stand singly, in opposition to those compositions called *groups*.

Figure, in conics, the rectangle under the latus rectum and transversum, in the hyperbola and ellipsis.

Figure, in fortification, the interior polygon, which is either regular or irregular. It is called a regular figure, when the sides and angles are all equal.

Figures are either Circumscribed or Inscribed, Equal, Equilateral, Similar, Regular, or Irregular. *See* these words.

Figure of the Diameter, a name given to the rectangle under a diameter and its perimeter, in the ellipsis and hyperbola.

FILLET, (from the French *filet*, a band) a small member, consisting of two planes at right angles, used to separate two larger mouldings, to strengthen their edges, or to form a cap or crowning to a moulding, or sometimes to terminate a member, or series of members.

The fillet is one of the smallest members used in cornices, architraves, bases, pedestals, &c.

It is called by the French, *reglet*, *bande*, and *bandelette;* by the Italians, *lista* or *listella*.

Fillet, in carpentry or joinery, any small timber scantling, equal to, or less than, battens: they are used for supporting the ends of boards, by nailing them to joists or quarters, &c., as in sound-boarding, and in supporting the ends of shelves.

Fillet Gutter. *See* Guttering.

FILLING-IN PIECES, in carpentry, short timbers, less than the full-length, fitted against the hips of roofs, groins, braces of partitions, &c., which interrupt the whole length.

FINE-SET, when the iron of a plane has a very small projection below the sole, so as to take a very thin broad shaving, it is said to be *fine-set*.

FINE STUFF, in plastering. *See* Plastering.

FINIAL, (from the Latin, *finio*, to finish,) in the pointed style of architecture, a termination to a building, or principal part, in the form of a flower or knop of foliage; used in high-pointed pediments, canopies, pinnacles, &c. It is usually in the form of a lily, trefoil, acorn, pomegranate, endive, &c., or consists of four or more of the leaves which compose the crockets tied up in one bunch.

FINISHING, a term frequently applied to the termination of a building, as also to the interior, in the plaster-work, in giving the last coat; and very frequently to the joiner's work, as in the architraves, bases, surbases, &c.

Finishing, in plastering. *See* Plastering.

FIR, (from the Welsh *fyrr*,) a species of timber much used in building. The native fur of this country is called *Scottish fir*, which is chiefly employed in out-houses, offices, &c. It is much inferior to the Baltic timber, which is used wherever durability is required. *See* Timber.

Fir, *Wrought*, that which is planed upon the sides and edges.

Fir, *Wrought and framed*, such as is both planed and framed.

Fir, *Wrought, framed, and rebated*, is what its name imports.

Fir, *Wrought, framed, rebated, and beaded*, is what its name imports.

Fir-Boards, the same as deal-boards. *See* Deal.

Fir-framed, is generally understood of rough timber framed, without undergoing the operation of the plane.

Fir-in-bond, a name given to all timber built in a wall, as bond-timbers, lintels, wall-plates, and templets.

Fir-Poles, small trunks of fir-trees from ten to sixteen feet in length, used in rustic buildings and out-houses.

Fir-no-labour, rough timber employed in walling, without framing or planing.

FIRE-BRICKS, are made from a natural compound of silica and alumina, which, when free from lime and other fluxes, is infusible under the greatest heat to which it can be subjected. Fire-bricks are brought to London from Stourbridge and from Wales; they are also made near Windsor. *See* Brick, and Windsor Bricks.

Fire-Engine, a term formerly applied to the steam-engine, but now confined to those machines which extinguish fires by throwing water from a jet upon the burning materials.

Fire-Escape, a machine for escaping from windows when houses are on fire.

Fire-Place, that space in an apartment where the fuel is consumed in communication with a flue through which the proceeds of combustion are carried away. In modern houses the fire-place is usually taken out of the space within the apartment, and flanked by projecting walls, upon which is carried up a flue, also projecting within the apartment, but in ancient houses the fire-place and flue were often taken out of the thickness of the wall, or projected outwards on the exterior of the building.

The most ancient fire-places in England, now existing, are those at Rochester and Conisborough Castles, which date of the twelfth century. The former is deeply recessed, with a semi-circular back, while the back of the former is flat, and not recessed at the level of the floor, but slopes backward as it rises; the hearth consequently projects into the room, but is covered by a hood which projects from the wall to collect the smoke. We have not many specimens of Early English work, but in the later styles they are more frequent. In Early English and Decorated buildings fire-places are not often very deeply recessed, and sometimes not at all, but they are frequently covered with projecting hoods. In the Perpendicular style they are generally entirely recessed, and in that case are without the hood; some specimens of this period are of a very ornamental description.

Fire-proof Houses, such as are built without the use of any combustible matter: for this purpose, vaulted or cast-iron floors and roofs should be employed in every apartment. Vaulting is well adapted to the lower story of a building, but if used in the upper stories, the walling must be carried up very thick, in order to resist the thrust of the arches; and this extra substance not only darkens the apartments, but occasions an enormous expense. The builder is therefore obliged to have recourse to other modes of construction for common purposes. The most convenient substitute is cast-iron joists, vaulted between with brick, or covered with cast-iron boards flanged and keyed together.

Mr. Bartholomew strongly recommends that roofs should be so constructed as to lessen as much as possible the possibility of fire. "It should be," he observes, "the architect's study, in all roofs, to have as little as possible that will either burn or rot; if the roof-trusses were made of cast-iron, as Mr. Gwilt has made those to his restoration of the choir of St. Saviour's Church, Southwark; and if slight horizontal rafters, reaching from truss to truss, supported tiles of the ornamental description above referred to, (tiles made of burnt earth, moulded in the form of leaves, &c.,) all combustible materials might be banished from our invaluable cathedrals."—We quite agree with Mr. Bartholomew in principle, but, in such cases, would beg to recommend a vaulted stone roof in preference to one of iron.

The late Sir John Soane constructed nearly all the apartments of the Bank of England fire-proof, and without any

carpentry whatever; in his arches and domes, making use largely of hollow pots or cones of coarse earthenware; these, while strong enough not to crush, by their lightness relieve the walls in a great measure, both from the lateral thrust, and the perpendicular pressure, caused by the use of heavier materials.

A method of rendering the floors of houses fire-proof, has been adopted with success in many parts of France. After the joists are laid they are boarded over with rough boards, and these covered with a coating of plaster of about eight inches in thickness, above which are laid tiles of an ornamental description, or sometimes a floor of parquetry. In some instances, the boards on which the plaster is laid, are omitted altogether, and the plaster inserted between the joists. The staircases likewise are made of brick-nogging, and covered with tiles.

It is a cause of wonder and regret, that these or similar means for rendering buildings fire-proof, are not adopted in London, where so great a loss is annually sustained by neglect on this head: the immediate outlay would not be very much greater than at present, and in the end the practice would assuredly prove the more economical. Our timber partitions, roofs, and staircases would seem to be made for the purpose of burning; and when once a portion of a building takes fire, there is little chance of saving the remainder; whereas if the chambers, or at least the floors, were isolated by fire-proof partitions, a fire could readily be confined to that part of the building where it commenced.

But perhaps of all parts of a house, that which requires the greatest care in this respect is the staircase; it is no easy matter to calculate how great a loss of human life has been occasioned by recklessness on this point. The staircase forms a shaft to carry up the flames, and is one of the first things to be destroyed, thus cutting off the means of escape from persons above the ground-floor: if nothing else be attended to, surely our staircases should be rendered fire-proof.

Iron has of late years been much used for the purpose of rendering buildings more safe from the effects of fire, but we are inclined to think the success of this application doubtful. This material is generally used as a substitute for summers, girders, or bond-timber, in which instances wood is almost as secure as iron; for in the former cases, the timbers are of too great scantling thoroughly to ignite, and in the latter they are well protected, and will be seldom found more than charred on the exposed surfaces. Besides this, iron has its disadvantages, for it is liable to expand and contract under the influence of heat and cold, and is known by this means to destroy the brickwork.

FIRE-STONE, is used in joinery, for rubbing away the ridges made by the cutting-edge of the plane.

FIRMER,
FORMER, } *See* Tools.
FURMER,

FISH-POND, a reservoir of water, for breeding, feeding, and preserving fish.

FISTUCA, (Latin) in antiquity, an instrument of wood, used in driving piles. It had two handles, and being raised by pullies fixed to the head of large beams, was let fall directly on the piles; sometimes it was wrought by hand only.

FIXED AXIS, in geometry, the axis about which a plane revolves in the formation of a solid.

Fixed Points, in carpentry, the points at the angles of a piece of framing, or where any two pieces of timber meet each other in a truss. If a third piece join the meeting of the two, it may be pushed or drawn in the direction of its length, without giving any cross strain.

Fixed points are of the utmost use in shortening the bearings of the exterior timbers of the frame; neither is there any other method by which this can be so effectually done. When two sides of a frame are similar, any points in the length of the pieces may be supported by as many beams, extending between the opposite points: though this will keep the frame in *equilibrio*, it will not prevent it from being shaken by heavy winds, or lateral pressure.

FLAGS, thin stones used in paving, from one and a half to three inches thick, and of various lengths and breadths, according to the nature of the quarry.

FLAKE WHITE, in painting, lead corroded by the pressing of grapes, or a ceruse prepared by the acid of grapes. It is brought to England from Italy, and far surpasses, in the purity of its whiteness, and the certainty of its standing, all the ceruses of white-lead made with us in common. It is used in oil and varnish painting, for all purposes where a very clean white is required. Flake white should be procured in lumps, as brought over, and levigated by those that use it; as that which the colourmen sell ready prepared, is levigated and mixed up with starch, and often with white-lead, or even worse sophistications.

FLAMBOYANT, a name applied to a style of Gothic architecture prevalent in France in the 15th century, from the circumstance of the principal lines of the tracery converging together in the shape of flames. This undulating distribution of lines is the characteristic of the style, if it may be so termed. The tracery is frequently of a very elaborate character, and the ornamentation intricate and redundant, while at the same time the mouldings are meagre. These consist usually of large hollows separated with small and insignificant members of different contour, which gives the whole an appearance of poverty, ill contrasting with the richness of the tracery. The centre moulding in the mullions of windows, and similar positions, projects often to an unusual extent, so as to give it the appearance of weakness. Pillars, piers, jambs, and such like, are often devoid of capitals, the mouldings of arches which abut against them, dying into them without any finishing ornament. The more ornamented parts, such as foliage, &c., are very rich, and delicately carved, but are frittered away by the minuteness of their parts, thus losing all boldness and even distinctness of outline.

FLANK, (from the French, *flanc*,) that part of a return body which adjoins the front; as flank-walls. In town-houses, the flank-walls become party walls.

FLANK WALLS, in engineering, the same as the wing or return walls of a lock or bridge.

FLAPS, folds or leaves attached to the shutters of a window, which are not sufficiently wide of themselves to cover the sash-frames, or to exclude the light.

FLASHES, in engineering, a kind of sluices erected upon navigable rivers, to raise the water upon any shoals therein, while the vessels or craft are passing.

FLASHINGS, in plumbery, pieces of lead inserted in a wall for covering other pieces laid down for gutters, &c.

FLAT CROWN. *See* Corona.

FLATTING, in house-painting, a mode of painting in oil, without any gloss on the painted surface when finished. The paint is prepared with a mixture of oil of turpentine, which secures the colour; and when used in the finishing, leaves the paint quite dead, without gloss. This is of great importance to those who are desirous to have their rooms continue white. Flatting is only used for inside work, and rarely for any but principal rooms. Nut oil is sometimes used for the purpose, but not often, on account of its high price.

As useful a flatting as any, is such as is ground in poppy oil. It is pleasant in working, and leaves a beautiful white for some years; but it is rather expensive.

FLEMISH BOND, that method of laying bricks in which headers and stretchers appear alternately in the length of each course. The appearance of this work is generally preferred to that of English bond, for the external facings of walls, but the method of laying is much more complicated, and requires the insertion of a number of small pieces in carrying up the work, to fill up the interstices between the bricks. *See* BRICKLAYING.

FLEMISH BRICKS, in bricklaying, strong bricks, of a yellowish colour, used in paving; their dimensions are about $6\frac{1}{2}$ inches long, $2\frac{1}{2}$ broad, and $1\frac{1}{2}$ thick; 72 set upon their widest sides, or 100 on edge, will pave a yard square, allowing a quarter of an inch for the joints.

FLEXURE, or FLEXION, (from the Latin) the opposition of curvature at a given point, where a straight line becomes a tangent, having the curve on both sides of it, one portion of the curve being concave, and that on the other side of the point of contact, convex.

FLIGHT, in staircasing, a series of steps, whose treads are parallel, and terminate against a straight wall.

FLIGHT, *Leading*, } *See* STAIRCASING.
FLIGHT, *Returning*, }

FLIGHT, is also used in London for a whole stair, between two adjoining floors.

FLOAT, in plastering. *See* PLASTERING.

FLOAT-BOARDS, the boards fixed to undershot water-wheels, to receive the impulse of the stream.

FLOAT-STONE, among bricklayers. *See* BRICKLAYERS.

FLOATED LATH AND PLASTER, set fair for paper. *See* PLASTERING.

FLOATED, RENDERED, and SET, in plastering. *See* PLASTERING.

FLOATING, in plastering. *See* PLASTERING.

FLOATING BRIDGE. *See* BRIDGE.

FLOATING RULES, in plastering. *See* PLASTERING.

FLOATING SCREEDS, in plastering. *See* PLASTERING.

FLOOD-GATE, a gate or sluice, that may be opened or shut at pleasure, to give passage to, or retain the water of a river liable to be swollen by floods. Flood-gates are necessary in many situations; as, upon rivers where the water is retained for the service of mills, canals, navigations, docks, &c.

FLOOR, (from the Saxon) the lowest horizontal side of an apartment, for walking, or for performing different operations upon.

Floors were formerly covered with rushes, carpets being seldom used for such purposes, even at the close of Elizabeth's reign. In much earlier times, however, tapestry-cloths were occasionally used to rest the feet upon. Most of the old dramatists have frequent allusions in their works to the practice of strewing rushes in the principal apartments.

Floors are of various kinds, according to the materials of which they are constructed. Those made of brick and stone, are called *pavements;* those of earth are called *earthen floors;* those of plaster, *lime floors;* and those of timber are called *timber floors.*

FLOOR, in carpentry, includes not only the boarding for walking upon, but all the timber-work for its support. Boarded floors should never be laid till the building is properly covered in, nor indeed till the windows are glazed, and the plaster dry. Previous to the lying of such floors, the boards ought to be rough-planed, and set out to season, a twelvemonth at least, before they are used; that the natural sap may be thoroughly expelled, and the shrinking prevented, which so frequently takes place when unseasoned timber is used. The best timber for flooring is yellow deal, well-seasoned. The quality of this material is such, that when laid, it will be easily kept of a good colour; whereas white timber is liable to become black in a very short time.

Narrow boards are called *battens;* these should never exceed seven inches in width, nor be less than an inch in thickness.

Floors are nailed either at both edges, or at one edge; the longitudinal joints, or those in the direction of the fibres, are either square, ploughed and tongued, or rebated and lapped upon each other. Ploughed and tongued, and rebated joints may be used where the apartment is required to be air-tight, and where the stuff is thought not sufficiently seasoned. The heading-joints are either square or ploughed and tongued. In square longitudinal jointed floors, it is necessary to nail the boards on both edges: but where the boards are dowelled, ploughed and tongued, or rebated, one edge only may be nailed, as the grooving and tonguing, or lapping, is sufficient to keep the other edge down.

Battens used in flooring are of three kinds, and are denominated *best, second best,* and *common.* The best battens are those that are free from knots, shakes, sap, and cross-grained fibres; the second best are those free from shakes and sap, but in which small knots are suffered to pass. The common kind are such as remain after taking away the best and second best.

The best floors are dowelled and nailed only at the outer edge, through which the nails are made to pass obliquely into the joists, without piercing the upper surface of the boards, so that when laid no nails appear: the heading joints of such floors are most commonly grooved and tongued. Some workmen dowel the battens over the joists, but it makes firmer work to fix the dowels over the inter-joists. The gauge should be run from the under surface of the boards, which should be straightened on purpose.

In the most common kind of flooring, the boards are folded together in the following manner: supposing one board already laid, and fastened, a fourth, fifth, sixth, or other board, is also laid and fastened, so as to admit of two, three, four, five, or more boards, between the two, but which can only be inserted by force, as the capacity of the opening must be something less than the aggregate breadths of the boards, in order that the joints may be close when they are all brought down to their places; for this purpose a board may be thrown across the several boards to be laid, which may be forced down by two or more men jumping upon it: this done, all the intermediate boards are to be nailed down, and the operation is to be repeated till the whole is complete. This manner of flooring is called a *folded floor.*

In folded floors, less than four boards are seldom laid together. No attention is paid to the heading joints, and sometimes three or four joints meet in one continued line, equal in length to the aggregate of the breadths of the boards.

In dowelled floors, the distances to which the dowels are set, are from six to eight inches, generally one over each joist, and one over each inter-joist; and, as has been already observed, the heading-joints of this kind of floor are generally ploughed and tongued; and no heading-joint of two boards ought to be so disposed as to meet the heading-joint of any other two boards, and thereby form a straight line equal to the breadth of the two boards.

In common floors, the boards are always gauged from the upper side, then rebated from the lower side to the gauge lines, and the intermediate part adzed down, in order to

bring them to a uniform thickness. In doing this, great care should be taken not to make them too thin, which is frequently the case, and then they must be raised with chips, which present a very unstable resistance to a pressure upon the floor.

Flooring is measured by throwing the contents into square feet, and dividing them by 100, which is called a *square of flooring;* the number of hundreds contained in the superficial contents in feet are squares, and the remainder feet.

The method of measuring floors, is by squares of ten feet on each side; the dimensions being multiplied together, cut off two figures from the right of the product, and those towards the left give the number of squares, and the two on the right are feet.

EXAMPLE.—Suppose the length of a floor 28 feet, and the breadth 24.

$$\begin{array}{r} 28 \\ 24 \\ \hline 112 \\ 56 \\ \hline 6,72 \end{array}$$

The product gives six squares, seventy-two feet.

When a naked floor is squared, and the contents found, nothing is deducted for the chimney, because the extra thickness of the trimmers will make up for that deficiency.

FLOOR, in carpentry, the timbers which support the boarding, called also *naked flooring. See* CARCASE FLOORING, and NAKED FLOORING.

FLOOR also denotes any portion of a building upon the same level: as basement-floor, ground floor, one-pair floor, two-pair floor, &c., but when there is no sunk story, the ground floor becomes the basement; the expressions one-pair floor, two-pair floor, &c., imply the floor above the first flight of stairs above ground, the floor above the second flight of stairs above ground, &c.

The principal floor of every building is that which contains the principal rooms. In the country they are generally on the ground floor; but in town, on the one-pair-of-stairs floor.

FLOOR JOISTS, or FLOORING JOISTS, such joists as support the boarding in a single floor; but where the floor consists of binding and bridging-joists, the bridgings are never called floor-joists.

FLOORS OF EARTH, or EARTHEN FLOORS, are commonly made of loam, and sometimes, especially to malt on, of lime, brook-sand, and gun-dust, or anvil-dust from the forge; the whole being well wrought and blended together with blood. The siftings of limestone have also been found exceedingly useful when formed into floors.

Earthen floors for plain country habitations may be made as follows: take two-thirds lime and one of coal-ashes, well sifted, with a small quantity of loam clay: mix the whole together, and temper it well with water, making it up into a heap: let it lie a week or ten days, and then temper it again. After this, heap it up for three or four days, and repeat the tempering very high, till it becomes smooth, yielding, tough, and gluey. The ground being levelled, lay the floor with this material about two and a half or three inches thick, smoothing it with a trowel; the hotter the season, the better; and when it is thoroughly dried, it will make a good floor for houses, especially malt-houses. But should it be required to make the floor look better, take lime made of rag-stones well tempered with whites of eggs, and cover the floor about half an inch thick with it, before the under flooring is quite dry. If this be well done, and thoroughly dried, it will appear, when rubbed with a little oil, as transparent as metal or glass. In elegant houses, floors of this nature are made of stucco, or plaster-of-paris, beaten and sifted, and mixed with other ingredients. Well-wrought coarse plaster makes excellent safe upper floors for cottages, out-houses, &c., when spread upon good strong laths or reeds.

Very dry and comfortable floors may be formed by covering the area of the rooms with a level stratum of concrete, consisting of dry screened gravel or pounded stone, mixed with a small quantity of ground stone lime, or Portland cement, and laid about six inches in thickness; over this, and before it sets, should be sifted a few ashes, or some fine gravel; which, if worked in and well finished, gives a hard and even surface. This description of floor is similar to those used in Devonshire, which are proverbial for comfort and durability. The ordinary red paving tiles, 12 inches square, make very good, dry, and comfortable floors, and they are easily kept clean. Claridge's asphalte of Seyssel, has also been used for the floors of basement stories, and answers very well, especially in damp situations. For stables, railway-stations, and places of a similar description, perhaps there is nothing better than wood. The wood-pavement of the Metropolitan Wood Pavement Company, has been used with great success for such purposes—in the dock-yards by government; and by the railway companies, for their stations, &c.

FLOORING-CRAMP, a machine invented by Mr. Andrew Smith, for laying down floors. This machine is used with great facility, and enables a person accustomed to it, to get through his work with rapidity and ease; making very tight and close joints in his floors, with much less trouble than by the ordinary method.

FLOORING-MACHINE, a machine for preparing complete flooring boards with great dispatch, and in the most perfect manner: the several operations of sawing, planing, grooving, and tongueing, being all carried on at the same time, by a series of saws, planes, and revolving chisels.

FLOOR-TIMBERS, the timbers on which a floor is laid.

FLORID STYLE, in pointed architecture, that beautiful style which was practised in England during the reigns of Henry VII. and Henry VIII. Its general external character consists of large arched windows, with very obtuse angles at the summit, and with numerous ramifications, consisting of light cuspidated mullions, filled with a variety of polyfoils. The buttresses, instead of having always rectangular horizontal sections, frequently have those of polygons, as in Henry VII.'s chapel, and are crowned with cupolas. The walls are loaded with niches, pinnacles, and crockets, terminating in open mullion-work, forming a parapet, or kind of balustrade, finished with finials or spiracles. The walls are decorated interiorly with panelling, moulded string-courses, niches, canopies, and other kinds of tracery, vaulted over with fan-groins. *See* GOTHIC ARCHITECTURE.

FLUE, a passage for smoke in a chimney, leading from the fireplace to the top of the shaft, or into another passage. *See* CHIMNEY.

The same term is also applied to passages in walls made for the purpose of conducting heat from one part of a building to another.

Flues in hot-houses and vineries, frequently make numerous turns on the floor, and then ascend to the wall with several horizontal turnings.

In the construction of a stack of chimneys, particular care should be taken that the drawings show distinctly the turnings of the flues; this will prevent mistakes, and save the apartments from being incommoded with smoke.

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FLUSH, a term among workmen, signifying a continuity of surface in two bodies joined together. Thus in joinery, the style, rails, and munnions are generally made flush; that is, the wood of one piece on one side of the joint does not recede from that on the other.

Flush, in masonry or bricklaying, signifies the aptitude of two brittle bodies to splinter at the joints, when the stones or bricks come in contact when joined together in a wall.

Flush and Bead. *See* Bead and Flush.

FLUTES, or Flutings, prismatic cavities depressed within the surface of a piece of architecture at regular distances, generally of a circular or elliptic section, meeting each other in an arris; or meeting the surface in an arris, and leaving a portion of the surface between every two cavities of an equal breadth; or diminishing in a regular progression; according as the surface is plane or curved, or applied to a prismatic or tapering body.

When a portion of the surface is left between every two flutes, that portion is called a *fillet*. When the flutes are parallel, or diminish according to any law, the fillets are also parallel, or diminish in the same degree.

The proportion of each fillet to a flute is from a third to a fifth of the breadth of the flute. That species of fluting, in which the flutes meet each other without the intervention of fillets, is generally applied to the Doric order; and that with fillets, to the shafts of the Ionic and Corinthian orders. The flutes most frequently terminate in a spherical or spheroidal form, particularly in those which have fillets. In the Ionic order of the temple of Minerva Polias at Athens, the upper ends of the fillets of the shafts of the columns terminate with astragals, projecting from the surface of the fillet: the astragals may begin at a small distance from the top of the shaft, ascend upwards, and bind round the top of the flute. In the Corinthian order of the monument of Lysicrates, at Athens, the upper ends of the fillets break into leaves in a most beautiful manner. In the Doric examples of the temple of Theseus, and of the temple of Minerva at Athens, and of the portico of Philip king of Macedon, in the island of Delos, the upper ends of the flutes terminate upon the superficies of a cone immediately under the annulets, in a tangent to the bottom of the curve of the echinus of the capital. The same kind of termination takes place in the temple of Apollo at Cora, in Italy: but in this example, the conic termination of the flutes is not under the abacus, but a small distance down the shaft, leaving a small part quite a plain cylinder, and thus forming the hypotrochelean or neck of the capital. In other ancient examples of the Doric order, the flutes terminate upon a plane surface perpendicular to the axis of the columns, or parallel to the horizon, as in the Propylea at Athens. Palladio, and other Italian authors, have terminated the flutes of the shafts of their designs of Doric columns in the segments of spheres tanged by the surfaces of the fluting.

In the temple of Bacchus, at Teos, in Ionia, the lower extremities of the flutes descend into the scape of the column.

The Greeks never applied fluting to any member of the Doric order, except the shaft, and this was their general practice.

Fluting was used by the Romans almost in every plane, and in every cylindrical surface. *See* a very fine specimen in the corona of the cornice of the temple of Jupiter Stator, at Rome.

The number of flutes in the Doric order is twenty, and in the Ionic, Corinthian, and Composite, twenty-four. Flutes are sometimes filled with cables or staves, except in the Doric order. The cables do not reach higher than one-third of the entire column. *See* Column, Cable.

FLUXIONS, in mathematics, the analysis of infinitely small variable quantities, or a method of finding an infinitely small quantity, which being taken an infinite number of times, becomes equal to a quantity given. The doctrine of fluxions, first invented by Newton, is of great use in the investigation of curves, and in the discovery of the quadratures of curvilinear spaces and their rectifications.

FLYERS, a series of steps whose treads are all parallel.

FLYING BRIDGE. *See* Bridge.

FLYING BUTTRESSES, in pointed architecture, arches rising from the exterior walls up to those of the nave of an aisled fabric, on each side of the edifice, for counteracting the lateral pressure of a groined or vaulted roof.

The contrivance of flying buttresses is due to the architects of the middle ages, and shows their skill in the application of mechanics to the science of architecture. *See* Buttress.

FOCUS, (Latin) in geometry, and in the conic sections, a point on the concave side of a curve, to which the rays are reflected from all points of such curve.

Focus, an altar, a hearth or fire-place: the Latin motto, *pro aris et focis*, is said to be derived from this word.

Focus, of an ellipsis, hyperbola or parabola, is particularly defined under the heads of Elliptic Curve, Hyperbolic Curve, and Parabolic Curve.

FODDER, Fudder, or Fother, (Saxon) a certain quantity, proportioned by weight.

The weight of the fodder varies, in different counties, from $19\frac{1}{2}$ cwt. to 24 cwt. Among the plumbers in London, the fodder is $19\frac{1}{2}$ cwt., but at the Custom House 20 cwt. of 112lb.

FOILS, the small arcs in the tracery of Gothic windows, panels, &c., which are said to be trefoiled, quatrefoiled, cinquefoiled, multifoiled, &c., according to the number of arcs which they contain. An arch with foils in its tracery is called a *foiled arch*. *See* Cusp and Foliation.

Foils, Foliations, the spaces between the cusps employed in the ornamentation of Gothic buildings.

FOLDED FLOOR. *See* Floor.

FOLDING DOORS, such as are made in two parts, hung on opposite jambs, and having their vertical edge rebated, so that when shut, the rebates may lap on each other. To conceal the meeting as much as possible, a bead is most frequently run at the joint on each side of the doors.

FOLDING JOINT, a joint made like a rule-joint, or the joint of a hinge.

FOLDS, or Flaps, of shutters, those parts that are hinged to the shutters, and concealed behind when the shutters are in the boxings, so as to cover the breadth of the window when the shutter and flaps are folded out in the breadth of the aperture. Folds are necessary when the walls are so thin as not to admit of shutters of sufficient breadth, when put together, to cover the opening.

FOLIAGE, in architecture, an artificial arrangement of leaves, fruit, &c. *See* Ornaments.

FOLIATION. *See* Foils.

FONT, (from the Latin *fons*) the vessel used in churches to hold the water consecrated for the purposes of baptism.

In the early church, the baptistery formed a separate building, numbered amongst the exhedræ or outbuildings which were detached from the church, but enclosed within the consecrated area. Within the baptistery was the font or reservoir. These separate buildings continued to prevail till the sixth century, when all occasion for adult baptism ceased, and fonts within the church became general. Many baptisteries, however, still exist in various parts of the

Continent, although there seem to be no specimens in England, unless indeed we consider as such the building surrounding the font at Lutón church. This structure is octagonal, about twenty-eight feet high, having open arches at the sides, and a stone roof, the font being placed in the centre, thus forming a small oratory capable of holding seven or eight persons. A similar canopy occurs at Trunch, Norfolk, but it is of wood, and hexagonal.

The material in use for fonts, is for the most part of stone lined with lead, but we have some notice of fonts of metal; that at Canterbury is reported to have been of silver, and that taken from Holyrood Chapel and brought to St. Alban's was of brass. There is also a font at Chobham, Surrey, which consists of a leaden basin enclosed within a screen of oak panelling, the date of which is about A.D. 1600. The situation of the font is within the church, near the door, either in the aisle next the porch, against one of the piers between the aisle and nave, or in the nave near the west end.

The most rude fonts are in shape little better than large stones, without any definite external form, but having a space hollowed out at the top in the shape of a bason; such is that in the church of Little Maplestead. Norman fonts are either of a cylindrical or cubical form; but which shape is the earlier, it is not easy to decide. In some instances the cylindrical fonts taper towards the base; and at St. Martin's, Canterbury, the reverse proportion is adopted. Next to these forms came the square stone hollowed out in the centre, supported on a massive cylindrical stem, or on a central stem, and four smaller shafts, one at each corner, specimens of which form exist at Lincoln cathedral and Iffley church, Oxfordshire. In all these instances, the sides of the font are ornamented with rude sculpture in low relief, frequently of groups, and sometimes of single figures contained in shallow niches, as at Stanton Fitzwarren, Wilts. Symbolical representations are frequently introduced, as are also scenes from the Sacred Writings, especially of such events as relate to the subject of baptism. On the font at Castle Frome, Herefordshire, is a representation of the Baptism of Christ, which is a very favourite subject, the same occurring at Bridekirk, in Cumberland, and West Haddon, in Northamptonshire. Another usual subject is the Fall of Man, as at East Meon, Hants.

Early English fonts are in form very similar to those of the preceding style, but they are readily distinguished by their ornamentation, which consists of work peculiar to this style; the details also are of better execution. The octagonal was a new form introduced into this style. Decorated and Perpendicular fonts are for the most part octagonal, and most frequently supported on a central stem; many of them are of most beautiful form and workmanship. Those of the later period are usually covered with panelling, and have the sides filled up with armorial bearings. Hexagonal fonts are sometimes, though not commonly, found; we have instances at Carlisle cathedral, Farringdon, Berkshire; and Bredon, Worcestershire. Five and seven-sided fonts are extremely rare; of the former we have an example at Hollington, Sussex. At Patrington and Saddington, Leicestershire, we find fonts of twelve sides; and at Stainburn, Yorkshire, one of fifteen sides; but these are purely exceptions: the octagonal form is the most common, as it is also the most appropriate. The font is usually raised on one or more steps, the sides or risers of which are often in the later styles decorated with panelling, quatrefoils, &c. Fonts were furnished with covers, which Edmund, archbishop of Conterbury, A.D., 1236, ordered to be locked down. They were probably in the earlier periods merely flat lids of wood, but in later times they were carried up in the form of a spire to a great height, ornamented with pinnacles and buttresses, with crockets, finials, and other ornaments; and not unfrequently the whole of the sides were pierced with the most elaborate panelling.

FONTANA, DOMINIC, a distinguished architect, born in 1543, at a village on the lake of Como. Having acquired the elements of geometry, he went to Rome, where his elder brother John was a student in architecture. Here he applied himself most diligently to the study of the works of antiquity, and at length was employed by Cardinal Montalto, afterwards Pope Sextus V. Montalto had already begun to display the magnificence of his character, by undertaking the construction of the grand chapel of the Manger, in the church of St. Maria Maggiore. The pope, Gregory XIII., jealous of the munificence of his cardinal, took from him the means of his designs, and thus put a stop to the works. Fontana, with a spirit worthy of a great man, went on with the building at his own expense, which so gratified the cardinal, that when he was raised to the pontifical chair, he appointed Fontana to be his architect. The chapel and palace were finished in a splendid style; but this was a small part of the designs projected by Sextus. Besides completing the dome of St. Peter's, he resolved to contribute to its grandeur, by conveying to the front of its piazza the obelisk, of a single piece of Egyptian granite, which had formerly decorated the Circus of Nero.

This design had been contemplated by some of the predecessors of Sextus, but none had actually attempted it. Sextus summoned architects and engineers from all parts, to consult upon the best means of effecting his purpose; Fontana's plan obtained the preference, and he was able to execute what he had advanced in theory. This was regarded as the most splendid exploit of the age; and rewards and honours of the most magnificent kind were bestowed on Fontana and his heirs. He was afterwards employed in raising other obelisks, and in the embellishment of the principal streets of Rome. He built the Vatican library, and had begun to make considerable additions to that place; but they were interrupted by the death of Sextus. One of Fontana's great works was the conducting of water to Rome, the distance of fifteen miles, in an aqueduct supported on arcades. The successor of Sextus, Clement VIII., was prejudiced against the papal architect, and dismissed him; but his reputation caused him to be engaged by the viceroy of Naples as architect to the king. He accordingly removed to Naples, in 1592, where he executed many works of consequence. His last efforts were directed to a new harbour at Naples, but this he did not live to complete. He died at Naples in 1607, in his sixty-fourth year.

FOOT, (Saxon) a measure, either lineal, superficial, or solid. The lineal or long foot is supposed to be the length of the foot of a man, and consists of twelve equal parts called *inches;* an inch being equal to three barleycorns.

Thus the English standard foot (31 Edw. I.) is $=12$ lineal English inches, $=36$ barleycorns, $=16$ digits, $=4$ palms, $=3$ hands, $=5\frac{1}{3}$ nails, $=1\frac{1}{3}$ spans, $=1.5151$, Gunter's links, $=.938306$ feet of France, $=.3047$ metres of France.

Geometricians divide the foot into 10 digits, and the digit into 10 lines, &c.

The French divide their foot, as we do, into 12 inches; and the inch into 12 lines. *See* MEASURES.

The foot square is the same measure, both in length and breadth, containing 144 square or superficial inches, $=2.295684$ square links; and the glazier's foot in Scotland is $=64$ square Scottish inches.

The cubic, or solid foot, is the same measure in all the

three dimensions, containing 1728 cubic inches English =6.128 ale gallons=3.478309 cubic links=.0283 cubic metres or steres of France.

The foot is of different lengths in different countries. The Paris royal foot exceeds the English by nine lines and a half; the ancient Roman foot of the Capitol consisted of four palms, equal to eleven inches and seven-tenths English; the Rhinland, or Leyden foot, by which the northern nations go, is to the Roman foot as 950 to 1,000. The portions of the principal feet of several nations, compared with the English and French, are here subjoined.

The English foot being divided into one thousand parts, or into twelve lines, the other feet will be as follow:

	Th. Pts.	Ft.	Inch.	Li.
London . . . . . . Foot	1000	0	12	0
Paris foot, the royal, by Greaves	1068	1	0	9.7
Paris foot, by Dr. Bernard . .	1066	1	0	9.5
Paris foot, by Graham, from the measure of half the toise of the Chatelet, the toise containing six Paris feet	1065.416	1	0	9.8
By Monnier, from the same data	1065.351	1	0	9
From both these it may be fixed at	1065.4	1	0	9.4
Amsterdam . . . . . Foot	942	0	11	3
Antwerp	946	0	11	3.57
Dort	1184	1	2	2
Rhinland, or Leyden	1033	1	0	4
Lorrain	958	0	11	5
Mechlin	919	0	11	0
Middleburg	991	0	11	10
Strasburg	920	0	11	0
Bremen	964	0	11	6
Cologne	954	0	11	5
Frankfort on the Maine . . .	948	0	11	4
Spanish	1001	1	0	0
Toledo	899	0	10	7
Roman	967	0	11	6
Bononia	1204	1	2	5
Mantua	1569	1	0	9
Venice	1162	1	1	11
Dantzic	944	0	11	3
Copenhagen	965	0	11	6
Prague	1026	1	0	3
Riga	1831	1	9	11
Turin	1062	1	0	8
The Greek	1007	1	0	1
Old Roman	970	0	11	7.6
Roman foot, from the monument of Cossutius in Rome, by Greaves	967	0	11	7.2
From the monument of Statilius, by the same	972	0	11	7.9
Of Villalpandus, deduced from the congius of Vespasian . . .	986	0	11	9.9

Mr. Rapier, who industriously collected a variety of authorities relating to the measure of the old Roman foot, determined the mean to be nearly 968 thousandth parts of the London foot. And by an examination of the ancient Roman buildings in Desgodetz's *Edifices Antiques de Rome*, Paris, 1682, he concluded that the Roman foot, before the reign of Titus, exceeded 970 parts in 1000 of the London foot; and in the reigns of Severus and Diocletian fell short of 965.

The Paris foot being supposed to contain 1440 parts, the rest will be as follow:—

Paris . . . . Foot	1440
Rhinland	1391
Roman	1320
London	1350
Swedish	1320
Danish	1403
Venetian	$1540\frac{2}{5}$
Constantinopolitan	3120
Bononian	$1682\frac{2}{5}$
Strasburg	$1282\frac{5}{4}$
Nuremburg	$1346\frac{1}{4}$
Dantzic	$1721\frac{1}{2}$
Halle	1320

In Scotland, this measure of length, though consisting of twelve inches, exceeds the English foot, so that 185 of the former is equal to 186 of the latter. Accordingly the Scottish foot = 12 Scottish inches = $12\frac{1}{15}$ English inches, according to some, and $12\frac{12}{185}$ English inches, according to others. The glazier's foot in Scotland = 8 Scottish inches.

For a farther account of the foot, ancient and modern, and its proportions in different countries. *See* MEASURE.

FOOT-BANK, or FOOT-STEP, in fortification. *See* BANQUETTE.

FOOT-BASE, the moulding above the plinth of an apartment.

FOOT-BRIDGE, a narrow bridge for foot-passengers. *See* BRIDGE.

FOOT OF THE EYE DIRECTOR, in perspective, that point in the directing line which is made by a vertical plane passing through the eye and the centre of the picture.

FOOT OF A VERTICAL LINE, in perspective, that point in the intersecting line, which is made by a vertical plane passing through the eye and the centre of the picture.

FOOT-IRONS, in engineering, pieces of iron plate, used by navigators, or canal-diggers, to tie upon that part of the sole of their shoes with which they strike the top of their spade or grafting tool, in digging hard soil,

FOOT-PACE, in hand-railing, a flat space in some stairs, always situated between the starting, or first step, and the landing. *See* STAIRCASING.

FOOT-PACE, the dais or raised floor at the upper end of an ancient hall.

FOOT-STALL, the base or plinth of a pillar.

FOOTING-BEAM, a term used in Cumberland, Westmoreland, Somersetshire, and perhaps in other counties, for the tie-beam of a roof.

FOOTINGS, in bricklaying and masonry, projecting courses of stone, without the naked of each face of a superincumbent wall, used as a base to the wall, in order to prevent it from sinking and rocking by heavy winds.

FOOTING DORMANT, the tie-beam of a roof; the term is used in Westmoreland.

FORCE, (from the Latin, *fortis*, strong) in philosophy, the cause of motion in a body, when it begins to move, or when it changes its direction from the course in which it was previously moving. While a body remains in the same state, whether of rest or of uniform and rectilinear motion, the cause of its so remaining is in the nature of the body, which principle has received the name of *inertia*.

Mechanical force is of two kinds: that of a body at rest, by which it presses on whatever supports it, and that of a body in motion, by which it is impelled towards a certain point. The former is called by the names of *pressure*, *tension*, *force*, *vis mortua*, &c., the latter is known by the appellation of *moving force*, or *vis viva*. To the first of these are

referred *centrifugal* and *centripetal* forces because, though they also reside in the *vis viva*, they are homogeneous to weights, pressures, or tensions of any kind. For want of a true knowledge of the nature of force, we are accustomed to consider its measure by velocity, upon the supposition that, under precisely similar circumstances, the velocity is equal to the force; an hypothesis highly probable, though not easily demonstrable. Velocity itself is a compound idea, derived from a certain relation between time employed and space described. Thus, if two bodies be supposed to move uniformly upon two different lines, the distances which they describe upon their respective lines in any given time, may be measured and represented by some standard measure, from which we acquire an idea of their relative velocity or force; and considering velocity as an abstract number, it is said to be equal to the space, divided by the time; and thus we are led to consider velocity, or the space described in a given time, as the measure of force.

Force may also be expressed by other functions of velocity; for it may be proportional to the square or cube of the velocity; and La Place has very ingeniously proved that the difference between the proportionality of force to velocity, if any really exists, must be extremely small; whence he argues it is highly improbable that any does exist. If there were any material variation in this law, the relative motions of bodies on the surface of the earth would be sensibly affected by the motion of the earth; in other words, the effect of a given force would vary considerably, according as its direction coincided with, or was opposed to, that of the earth's motion. The effects of the same apparent forces would likewise vary in different seasons of the year; the velocity of the earth being less by about one-thirtieth in summer than it is in winter. But as no such variation is discernible, we may justly conclude the proportion between force and velocity to be as 1 to 1; that is, there is no difference. To illustrate this, suppose two bodies moving upon one straight line with equal velocities; by impelling one of them with a force which increases its original force, its relative velocity to the other body remains the same as if both had been primitively in a quiescent state. The space described by the body, in consequence of its original force, and of that which has been added to it, becomes equal to the sum of what each of them would have caused it to have been, described in the same time; therefore the force is proportional to the velocity.

This law, and that of *inertia* above alluded to, may be considered as derived from observation and experiment: they are simple and natural, and are sufficient to serve as a basis for the whole science of mechanics.

Early in the last century, a warm controversy arose relative to the measure of force, which was carried on with considerable acrimony, though it now appears that the question was rather about words than facts. Sir Isaac Newton had defined the measure of force to be "the mass of a body mutiplied into its velocity;" which definition was not only convenient for the philosophical investigation in which he was engaged; but was really mathematically just. But in another point of view, in which the effects of force may be said, without any impropriety, to depend on the mass multiplied into the square of the velocity, this product has been called the *vis viva*, and was considered by Bernouilli and Leibnitz as the true and universal measure of force, in opposition to Sir Isaac's definition; though it now appears that they were led into an error by not duly considering all the circumstances of the question at issue. The measure adopted by them, the *vis viva*, however, merits attention, as in all cases of practical machinery it is frequently the most accurate, and always the most useful; at the same time it implies no contradiction to the Newtonian definition. But the force thus measured ought to be distinguished by some appropriate name, *e. g.* the *vis mechanica;* the Newtonian measure being applied to the *vis motrix*, as suggested by Mr. Wollaston in the *Bakerian Lecture* for 1805.

Force, *Direction of*, the straight line which it tends to make a body describe.

Forces, *Composition of.* If two forces be conceived to act on a material point, it is evident that if they both act in the same direction, they will mutually increase each other's effect; but if they act in opposite directions, the point will move only in consequence of their difference, and it would remain at rest if the forces were equal. If the directions of the two forces make an angle with each other, the resulting force will take a mean direction; and it can be demonstrated geometrically, that if, reckoning from the point of intersection of the two directions of the forces, we take on these directions straight lines to represent them, and then form a parallelogram with such lines, its diagonal will represent their resulting force, both as to its direction and magnitude. The resulting force thus determined, which likewise represents the velocity of the moving point, may therefore be substituted as a force equivalent to the two component forces; and reciprocally, for any force whatever, we may substitute any two forces, which according to this rule would compose it. Hence we see that any force whatever may be decomposed into any two forces, parallel to two axes situated in the same plane, and perpendicular to each other. To effect this, it is only necessary to draw from the first extremity of the line representing the force, to other lines parallel to the axis, and to form with such lines a rectangle, whose diagonal will be the force required to be decomposed. The two sides of this rectangle, or parallelogram, will represent the forces into which the given force may be decomposed, parallel to such axis. If the force be inclined to a plane in position, a line in its direction may be taken to represent it, having one of its extremities on the surface of the plane, and the perpendicular falling from the other extremity will be the primitive force decomposed in the direction perpendicular to the plane. The straight line, which in the plane joins the other extremity of the line representing the force with the perpendicular (or the orthographic projection of the line of the plane) will represent the primitive force decomposed, parallel to the plane. This second partial force may itself be decomposed into two others, parallel to two axes in the same plane, perpendicular to each other. Thus we see that every force may be decomposed into three others, parallel to three axes perpendicular to each other; which axes are termed *rectangular co-ordinates.*

Hence we have a very simple mode of obtaining the resulting force of any number of forces supposed to act on a material point. This method was first adopted by Maclaurin, followed by La Grange, in the *Méchanique Analytique*, and also by La Place in the *Méchanique Céleste.* By decomposing each of these forces into three others, parallel to the given axes in position, and perpendicular to each other, we have all the forces parallel to the same axis reduced to one single force, which latter will be equal to the sum of the forces acting in the same direction, minus the sum of those acting in a contrary direction: so that the point will be acted on by three forces perpendicular to each other. From the point of intersection, or origin of the co-ordinates, take three right lines to represent them in each of their directions, and on such lines form a rectangular parallelopipedon, and the diagonal of this solid will represent the quantity and direction of the resulting force of all the forces acting on the point.

The principle of the composition of forces is of the most extensive utility in mechanics, and is in itself sufficient for determining the law of equilibrium in every case. Thus, if we successively compose all the forces, taking them by two's, and then take the result as a new force, we obtain one that s equivalent to all the rest, and which, in case of equilibrium, must equal 0, when the system under consideration has no fixed point; but if the conditions of the problem insist on an immoveable point, the resulting force must necessarily pass through it.

Though it is admitted by all writers on this subject, that the most abstruse propositions may be deduced from a few simple principles, yet few are found who entirely agree in their choice of such principles. The most advantageous, and indeed the most natural method, seems to be that wherein the relation between various forces in a state of equilibrium is first investigated, and then the consideration extended to a body in motion. If a body remain in equilibrium, at the same time that it is solicited by several forces, each force is supposed to produce only a tendency to motion, which is measured by the motion it would produce were it not checked by the power of the others: therefore, after expressing the effect of any one of the forces by unity, the relative force of the others may likewise be expressed by words or numbers.

La Place merely assumes the two foregoing principles, and speaks of them as experimental facts; while Dr. Young does not scruple to declare them capable of demonstration. (*See* his *Lectures.*) But this difference of opinion is of little importance, since the principles themselves are universally admitted.

La Grange has founded the whole doctrine of the equilibrium of forces on the well-known principle of the lever, the composition of motion, and the principle of virtual velocity; each of which we shall here notice.

The *principle of the lever* may be derived from the composition of forces, or even from much less complicated considerations.

Archimedes, the earliest author on record, who attempted to demonstrate the property of the lever, assumes the equilibrium of equal weights at equal distances from the fulcrum, as a mechanical axiom; and he reduces to this simple and primitive case that of unequal weights, by supposing them, when commensurable, to be divided into equal parts, placed at equal distances on different points of the lever, which may thus be loaded with a number of small equal weights, at equal distances from the fulcrum.

The principle of the straight and horizontal lever being admitted, the law of equilibrium in other machines may be deduced from it. Though it is not without difficulty that the inclined plane is referred to this principle; the laws relative to which have been but lately known.

Stevinus, mathematician to Prince Maurice of Nassau, first demonstrated the principle of the inclined plane by a very indirect, though curious mode of reasoning. He considers the case of a solid triangle resting on its horizontal base, whose sides then become two inclined planes: over these he supposes a chain to be thrown, consisting of small equal weights threaded together; the upper part of such chain resting on the two inclined planes, and the lower ends hanging at liberty below the foot of the base. His reasoning is, that if the chain be not in equilibrio, it will begin to slide along the plane, and would continue so to do, the same cause still existing, for ever; thus producing a perpetual motion. But as this implies a contradiction, we must conclude the chain to be in equilibrio; in which case, as the efforts of all the weights applied to one side would be an exact counterpoise to those applied to the other, and the number of weights would be in the same ratio as the lengths of the planes; he concludes that the weights will be in equilibrio on the inclined planes when they are to each other as the lengths of the planes; but that when the plane is vertical, the power is equal to the weight; and that therefore, in every inclined plane, the power is to the weight as the height of the plane to its length.

Virtual velocity is that which a body in equilibrium is disposed to receive whenever the equilibrium is disturbed; in other words, it is what a body actually receives in the first moment of its motion.

The principle of virtual velocity, in its most general form, is as follows: suppose a system in equilibrium composed of a number of points, drawn in any direction, by whatever forces, to be so put in motion, as that every point shall describe an infinitely small space, indicative of its virtual velocity; the sum of the forces being each multiplied by the space described by the point to which it is applied, in the direction of the force, will equal 0; the small spaces described in the direction of the forces being estimated as positive, and those in a contrary direction as negative. Galileo, in his *Treatise on Mechanical Science*, and in his *Dialogues*, proposes this principle as a general property in the equilibrium of machines; he appears to have been the first writer on mechanics, who was acquainted with it. His disciple Torricelli was the author of another principle, which seems to be but a necessary consequence of Galileo's. He supposes two weights to be so connected, that however placed, their centre of gravity shall neither rise nor fall; in every situation, therefore, they will be in equilibrio. He contents himself with applying this principle to inclined planes; but it equally applies to all machines.

Des Cartes deduced the equilibrium of different forces from a similar principle; but he presented it under another, and less general point of view, than Galileo had done; for he argues that to lift a given weight to a certain height, precisely the same force is requisite that would be sufficient to raise a heavier to a height proportionally less, or a lighter to a height proportionally greater; therefore two unequal weights will be in equilibrio, when the perpendicular spaces described by them are reciprocally proportioned to them. In the application of this principle, however, only the spaces described in the first instant of motion are to be considered; otherwise the accurate law of equilibrium will not be attained.

Another principle, recurred to by some authors in the solution of problems relative to the equilibrium of forces, arises out of the foregoing, *viz.* When a system of heavy bodies is in equilibrio, the centre of gravity is the lowest possible. For the centre of gravity of a body is the lowest, when the differential of its descent is 0, as can be demonstrated from the principle *de maximus et minimus;* that is, when the centre of gravity neither ascends nor descends by an infinitely small change in the position of the system.

J. Bernouilli first perceived the great utility of generalizing this principle of virtual velocity, and applied it to the solution of problems; in which he was followed by Varignon, who has devoted the whole of the ninth section of his *Nouvelle Mechanique* to demonstrate its truth and exemplify its utility in various cases in statics.

In the *Mémoires de l' Académie* for 1740, Maupertuis proposed another principle, originating in the same source, under the title of "The Law of Repose;" which was afterwards extended by Euler, and explained in the Memoirs of the Berlin Academy for 1751: and the principle assumed by Mons. Courtivron, in the *Mémoires de l' Académie* for 1748-9, is of the same nature: *viz.*, that of all the situations which a system of bodies can successively take, that wherein the

system must be placed to remain in equilibrio, is that in which the *vis viva* is either a maximum or a minimum, because the *vis viva* is the sum of the respective masses composing the system, each multiplied into the square of its velocity.

Of all these methods, that of virtual velocity appears to be most generally useful; indeed all the others are derived from it, and are serviceable in proportion as they approach nearer to it. La Grange has given practical examples of the analytical processes for determining general formulæ or equations for the equilibrium of any system; and La Place has demonstrated the principle on which the calculus is founded.

In the foregoing observations, force is supposed to be the product of the mass of a material point, by the velocity it would receive if entirely free. By confining these considerations to the case of a single material point, the conditions of equilibrium will be found to be analogous to those above spoken of, but much simplified.

The most elementary equation to express the state of equilibrium of a material point, acted on by any number of forces, is, that every force, multiplied by the element of its direction, equals 0: thus, suppose the point to change its position in an infinitely small degree in any direction; then, in the case of equilibrium, if every force be multiplied by the elementary space approached to, or receded from by the point, the force being estimated in its direction, the product will be 0.

Here the point is supposed to be free; but if constrained to move on a curved surface, it will experience a reaction equal and contrary to the pressure which it exerts on such surface, but perpendicular to it, or in the direction of the radius of the curve. This reaction may be considered as a new force, which, multiplied by the elements of its direction, must be added to the former equation. But if the variation of position, instead of being taken arbitrarily, be taken upon the curve, so as not to alter the conditions of the problem, the preceding equation will still hold good, because the elementary variation of the radius is equal to 0, as is evident from inspection. Again, if the magnitude of any force, or its intensity, multiplied by the distance of its direction from any fixed point, be denominated its *moment*, relatively to such point, it will be found that the sum of the moments of the producing forces is always equal to that of the resulting force; and in case of equilibrium the sum of the moments of all the forces equals 0.

If the forces acting on a point, or on a system of points, be not so proportioned as to maintain the system in equilibrium, a motion must necessarily take place, the laws of which may be deduced from an extension of the principles laid down for investigating the state of equilibrium; a method pursued by La Grange, and after him by La Place. The former combines the principle of virtual velocities with that of D'Alembert, which is very simple, and, though long unobserved, may be considered as an axiom. It is as follows:

If several bodies have a tendency to motion, in directions, and with velocities, which they are constrained to change in consequence of their reciprocal reaction; the motion so induced may be considered as composed of two others, one of which the bodies actually assume, and the other such, that had the bodies been only acted upon by it, they would have remained in equilibrium. This theorem is not of itself sufficient to solve a problem, because it is always necessary to derive some condition relative to the equilibrium from other considerations; and the difficulty of determining the forces and the laws of their equilibrium, sometimes renders this application more difficult, and the process more tedious, than if the solution were performed upon some principle more complex and more indirect. To obviate this objection, therefore, La Grange attempted to combine the principle of D'Alembert with that of virtual velocity; in which he was so successful, that he was enabled to deduce the general equations relating to the forces acting on a system of bodies. His description of the method is as follows:

To form an accurate conception of the mode in which these principles are applied, it is necessary to recur to the general principle of virtual velocity, *viz.* When a system of material points, solicited by any force, is in equilibrium, if the system receive ever so small an alteration in its position, every point will naturally and consequently describe a small space; each of which spaces being multiplied by the sum of each force, according to the direction of such force, must equal 0.

Now, supposing the system to be in motion, the motion that each point makes in an instant may be considered as composed of two, one of them being that which the point acquires in the following instant; consequently, the other must be destroyed by the reciprocal action of the points or bodies upon each other, as well as of the moving forces by which they are solicited. There will therefore be an equilibrium between these forces and the pressures or resistances resulting from the motions lost by the bodies from one instant to another. Therefore, to extend to the motion of a system of bodies, the formulæ of its equilibrium, it is only necessary to add the terms due to the last-mentioned forces.

The decrement of the velocities, which every particle has in the direction of three fixed rectangular co-ordinates, represents the motions lost in those directions; and their increment represents such as are lost in the opposite directions. Therefore, the resulting pressures or forces of these motions destroyed will be generally expressed by the mass multiplied into the element of the velocity, divided by the element of the time; and their directions will be directly opposite to those of the velocities.

By these means the terms required may be analytically expressed, and a general formula obtained for the motion of a system of bodies, which will comprehend the solution of all the problems in dynamics; and a simple extension of it will give the necessary equations for each problem.

A great advantage derived from this formula is, that it gives directly a number of general equations, wherein are included the principles or theorems, known under the appellations of *conservation of the vis viva; conservation of the motion of the centre of gravity; conservation of equal areas;* and the *principle of the least action.*

Of these, the first, the *conservation of the vis viva*, was discovered by Huygens, though under a form somewhat different from that which we now give to it. As employed by him, it consisted in the equality between the ascent and descent of the centre of gravity of several weighty bodies, which descend together, and then ascend separately by the force they had respectively acquired. But by the known properties of the centre of gravity, the space it describes in any direction is expressed by the sum of the products of the mass of each body by the space such body has described in the same direction, divided by the sum of the masses. Galileo, on the other hand, has shown in his problems, that the vertical space described by a weighty body in its descent is proportional to the square of the velocity acquired, and by which it will reascend to its former elevation. The principle of Huygens is therefore reduced to this; that in the motion of a system of bodies, the sum of the masses by the squares of the velocities is constantly the same, whether the bodies descend conjointly, or whether they freely descend separately through the same vertical channel.

This principle had been considered only as a simple

theorem of mechanics, till J. Bernouilli adopted the distinction, established by Leibnitz, between such pressures as act without producing actual motion, and the living forces, as they were termed, which produced motion; as likewise the measures of these forces by the products of the masses by the squares of the velocities. Bernouilli saw nothing in this principle but a consequence of the theory of the *vis viva*, and a general law of nature, in consequence of which, the sum of the *vis viva* of several bodies preserves itself the same, as long as they continue to act upon each other by simple pressures, and is always equal to the simple *vis viva*, resulting from the action of the forces by which the body is really moved. To this principle he gave the name of *conservatio vivium vivarum*, and successfully employed it in the solution of several problems that had not before been effected.

From this same principle, his son, D. Bernouilli, deduced the law of the motion of fluids in vases, which he explains in the *Berlin Memoirs* for 1748: a subject before but little understood.

The advantage of this principle consists in its affording immediately an equation between the velocities of the bodies and the variable quantities which determine their position in space; so that when by the nature of the problem these variable quantities are reduced to one, the equation is of itself sufficient for its solution, as in the instance of the problem relating to the centre of oscillation. In general, the conservation of the *vis viva* gives a first integral of the several differential equations of each problem, which is often of great utility.

The second principle above alluded to, *conservation of the motion of the centre of gravity*, is given by Sir Isaac Newton in his *Principia*, as an elementary proposition; where he demonstrates, that the state of repose or of motion of the centre of gravity of several bodies, is not altered by the reciprocal action of these bodies, in any manner whatever: so that the centre of gravity of bodies acting upon each other, either by means of cords or of levers, or by the laws of attraction, remains always in repose, or move uniformly in a direct line, unless disturbed by some exterior action or obstacle. This theorem has been extended by D'Alembert, who has demonstrated, that if every body in the system be solicited by a constant accelerating force, either acting in parallel lines, or directed towards a fixed point, but varying with the distance, the centre of gravity will describe a similar curve to what it would have done, had the bodies been free. And, it might be added, the motion of this centre will be the same as if all the forces of the bodies were applied to it, each in its proper direction. This principle serves to determine the motion of the centre of gravity, independently of the respective motions of the bodies; and thus it will ever afford three finite equations between the co-ordinates of the bodies and the times; and these equations will be the integrals of the differential equations of the problem.

The third principle, the *conservation of equal areas*, is more modern than the two former, and appears to have been separately discovered by Euler, D. Bernouilli, and D'Arcy, about the same period, though under different forms.

Euler and Bernouilli describe the principle thus: In the motion of several bodies round a fixed centre, the sum of the products of the mass of each body by the velocity of rotation round the centre, and by its distance from the same centre, is always independent of any mutual action exerted by the bodies upon each other, and preserves itself the same as long as there is no exterior action or obstacle. Such is the principle described by D. Bernouilli in the first volume of the *Memoirs of the Berlin Academy*, 1746; and by D'Alembert, in the same year, in his *Opuscula*. The Chevalier D'Arcy, also in the same year, sent his Memoir to the Academy of Paris, though it was not printed till 1752, wherein he says, "The sum of the products of the mass of each body by the area traced by its radius vector about a fixed point, is always proportional to the times."

This principle, however, is only a generalization of Sir Isaac's theorem of equality of areas described by centripetal forces: and to perceive its analogy, or rather its identity with that of Euler and Bernouilli, it is only requisite to recollect, that the velocity of rotation is expressed by the element of the circular arc divided by that of the time; and that the first of these elements multiplied by the distance from the centre, gives the element of the area described about it. It appears then that this latter principle is only the differential expression of that of the Chevalier, who afterwards gave the same principle in another form, which renders it more similar to the preceding, viz. The sum of the products of the masses by the velocities, and by the perpendiculars drawn from the centre to the direction of the forces, is always a constant quantity. Under this point of view, M. D'Arcy set up a kind of metaphysical principle, which he denominates the *conservation of action*, in opposition to, or rather as a substitute for, the principle of the least action.

But leaving these vague and arbitrary denominations, which neither constitute the essence of the laws of nature, nor are able to raise the simple results of the known laws of mechanics to the rank of final causes, let us return to the principle in question, which takes place in every system of bodies acting on each other in any manner whatever, whether by means of cords, inflexible lines, attractions, &c., and also drawn by forces directed to a centre, whether the system be entirely free, or constrained to move about it. The sum of the products of the masses by the areas described about this centre, and projected on any plane, is always proportional to the time; so that by referring these areas to three rectangular planes, we obtain three differential equations of the first order, between the time and the co-ordinates of the curves described by the bodies; and in these equations, the nature of the principle properly exists.

The fourth principle, that *of the least action*, was so denominated by Maupertuis, and has since been rendered celebrated by the writings of several illustrious authors. Analytically it is as follows: In the motion of bodies acting upon each other, the sum of the products of the masses by the velocities, and by the spaces described, is a minimum. Maupertuis has published two memoirs on this principle; one in the *Transactions of the Academy of Sciences*, for 1744; the other, in those of the Academy of Berlin, 1746; wherein he deduces from it, the laws of reflection and refraction of light, and those of the shock of bodies. It appears, however, that these applications are not only too partial for establishing the truth of a general principle, but they are in themselves too vague and arbitrary; so that the consequences attempted to be deduced become uncertain: this principle, therefore, deserves not to be classed with the three foregoing. There is, however, one point of view, in which it may be considered as more general and exact, and which alone merits the attention of geometricians. Euler first suggested the idea at the close of his *Treatise on Isoperimetrical Problems*, published at Lausanne, in 1744, wherein he shows that in trajectories described by central forces, the integral of the velocity multiplied by the element of the curve is constantly either a maximum or a minimum; but he knew of this property only as pertaining to insulated bodies. La Grange extended it to the motion of a system of bodies acting on each other, and demonstrated a new general principle, viz. That the sum of the products of the masses by the integrals of the

velocities multiplied by the elements of the spaces described, is always a maximum or a minimum.

From a combination of this latter principle with that of the conservation of the *vis viva*, many difficult problems in dynamics may be solved; as exemplified by La Grange in the *Memoirs of the Academy of Turin*, vol. ii.

La Place, in the *Méchanique Céleste*, treats the doctrine of dynamics much in the same manner as La Grange, but he carries his investigations much farther. He agrees with that writer in adopting the principle of D'Alembert, and in resolving every motion into two; that which the particle had in the preceding instant, and that which would have maintained it in equilibrio: but he differs from him in not admitting the principle of virtual velocity to be assumed as a fundamental axiom; which he demonstrates by a regular train of inductions.

After having established nearly the same formulæ, or differential equations, and deduced all the general principles in the manner just described, he introduces others in the nature of corollaries, many of which merit peculiar consideration. From the principle of the conservation of areas, it follows, that in the motion of a system of bodies solicited only by their mutual attraction and by forces directed to the origin of the co-ordinates, there exists a plane passing through such origin, which possesses the following remarkable properties:

1. That the sum of the areas traced on the plane by the projections of the *radii vectores* of the bodies, and multiplied by their respective masses, will be the greatest possible.

2. That such sum is also equal 0 upon all the planes perpendicular to it.

As the principle of the *vis viva*, and that of areas, subsist relatively to the centre of gravity, even though the latter be supposed to have a rectilinear uniform motion, it follows, that a plane may be determined as passing through this moveable origin, on which the sum of the areas, described by the projections of the radii vectores, and multiplied respectively by their masses, may be the greatest possible. This plane being parallel to the one passing through the fixed origin, satisfies the same conditions; and another plane passing through the centre of gravity, and determined according to the foregoing conditions, will remain parallel to itself during the motion of the system; a circumstance of considerable utility and importance. To this we may add, that any plane parallel to the last-mentioned, and passing through any of the bodies, partakes of analogous properties.

La Place next examines how far these results would be changed, if other relations subsisted between the force and the velocity. Force, he observes, may be expressed in a great variety of ways relatively to the velocity, besides that of the simple law of proportionality, without implying any mathematical contradiction. Suppose the force to be some other function of the velocity, (analytically expressed by $F = \phi\, v$;) in this case the principle of the *vis viva* will be found to obtain in all the possible mathematical relations between the force and the velocity; the *vis viva* of a body being the product of its mass by double the integral of its velocity, multiplied by the differential of the function of the velocity indicative of the force.

The uniform rectilinear motion of the centre of gravity is preserved by the law of nature alone; by which also the conservation of areas subsists. But a principle analogous to that of the least action will be found to belong to every possible relation between force and velocity.

The principle of the least action is not so obvious as the others that have been mentioned, being more remote from the elementary theorems, from which they are all derived; nevertheless, if it be directly and mathematically deducible from the same simple principles, it must immediately be divested of all pretension to the dignity of a final cause; to which it can have no greater claim than any other remarkable numerical property; for the reverse would imply a mathematical contradiction. The fact, which is curious, may be thus analytically stated: Suppose a material point to move under the impulse of several forces from one point to another; the curve which it describes possesses the remarkable property of having the integral or continued product of the velocity (determined by previous considerations) when multiplied into the element of the curve, less than any other curve passing through the same points.

Maupertuis, who discovered this principle, carried it no further than to single bodies; Euler established its generality; and La Grange extended it to a system of bodies acting on each other, as already noticed. The principle of the least action being therefore admitted as an established theorem, it may be resorted to for the solution of problems, and for determining the trajectories of bodies moving in space; but in point of practical utility, the necessary calculations are so much more complex and difficult than the more usual methods of investigation, that the latter are greatly to be preferred to it.

Upon these leading principles of the doctrine of forces, as laid down by the most eminent writers on the subject, it is to be remarked, that they are for the most part mere developments of theorems easily deducible from the Newtonian laws of motion; and that many of them were even established by Newton himself. This generalization of mechanical principles possesses, however, the advantage of enabling us to take a more enlarged and comprehensive view of the subject, than we could do by the consideration of a single problem.

Forces, which become the subject of mathematical computation, may be appropriately divided into the three following classes:

1. Such as act instantaneously, or for a short interval of time, and impart uniform motion to a particle subjected to their action; provided it be not solicited by any force, and is free to move in any direction.

2. Such as, acting with a continued uniform intensity, oblige a material particle, at liberty to obey their impulse, to describe its path with a uniformly accelerated motion.

3. Those, whose intensities, perpetually varying, though according to some known law, produce a complicated action, whose circumstances can only be investigated by means of the integral calculus, or some analogous methods.

Forces whose mode of action is too arbitrary and uncertain to be included in either of these classes, may be considered as foreign to the present investigation.

The reader who wishes to have more scientific information on this subject, may refer to Gregory's Mechanics; Dr. Jackson's Theoretical Mechanics; and may also consult Marat's Mechanics, Wood's Mechanics, or Whewell's Mechanics. Professor Leslie also, (in his Elements of Natural Philosophy,) has given an excellent popular illustration, by supposing the threads to act on light spiral springs adapted to measure the forces, and commonly called spring steel-yards; but he acknowledges pulleys and weights have some advantages. By reversing the action of the springs, they might be applied, with much advantage, to show the relations of compressing forces, by lecturers on mechanical science.

FORCE, *Mechanical.* Desaguliers, in his *Experimental Philosophy*, has many curious and useful observations concerning the comparative forces of men and horses, and the best mode of applying them. And Dr. Young, in his *Lectures*, has given a table of a similar nature, compiled chiefly from the writings of Desaguliers and Coulomb, another writer, who has also displayed considerable ingenuity in pursuing

the subject. The following extract cannot fail of being useful to all concerned in practical mechanics.

In his introduction to his Table, Dr. Young observes, that to compare the different estimates of moving power, it will be convenient to take an unit as the mean effect of the labour of an active man, and without impediment. This will be found, on a moderate estimation, sufficient to raise 10lb. to the height of 10 feet in a second, for 10 hours in a day; or to raise 100lb., which is the weight of twelve wine gallons of water, 1 foot in a second, or 36,000 feet in a day; or 3,600,000lb., or 432,000 gallons, 1 foot in a day. This we may call a force of 1 continued 36,000."

"*Immediate Force of Men without Deduction for Friction.*

	Force.	Continuation.	Days' Work.
A man, weighing 133lb. (French) ascended 62 feet (French) by steps in 34″, but was completely exhausted. *Amontons*	2.8	34″	
A sawyer made 200 strokes of 18 inches (French) each, in 145″, with a force of 25lb. (French). He could not have gone on above 3 minutes. *Amontons*	6.	145″	
A man can raise 60lb. (French) 1 foot (French) in 1″, for 8 hrs. a day. *Bernouilli.*	69.	8^h	.552
A man of ordinary strength can turn a winch with a force of 30lb. and with a velocity of $3\frac{1}{2}$ feet in 1″, for ten hours a day. *Desaguliers*	1.05	10^h	1.05
Two men working at a windlass, with handles at right angles, can raise 70lb. more easily than one can raise 30lb. *Desaguliers.*	1.22		1.22
A man can exert a force of 40lb. for a whole day, with the assistance of a fly, when the motion is pretty quick, as about 4 or 5 feet in 1″. *Desaguliers.* Lect. IV. But from the annotation, it appears doubtful whether the force be 40lb. or 20lb	2.		.2
For a short time a man may exert a force of 80lb. with a fly, "when the motion is pretty quick." *Desaguliers*	3.	1″	
A man going up stairs, ascends 14 metres in 1′. *Coulomb*	1.182	1	
A man going up stairs for a day, raises 205 kilogrammes to the height of a kilometre. *Coulomb*			.412
With a spade a man does $\frac{19}{20}$ as much as in ascending stairs. *Coulomb*			.391
With a winch a man does $\frac{5}{8}$ as much as in ascending a stairs. *Coul*			.258
A man carrying wood up stairs, raises, together with his own weight, 109 kilogrammes to one kilometre. *Coulomb*			219.
A man weighing 150lb. (French) can ascend by stairs 3 feet (French) in 1″ for 15″ or 20″. *Coulomb*	5.22	20″	
For half an hour, 100lb. (French) may be raised 1 foot (French) in 1″. *Coulomb*	1.152	30′	
According to Mr. *Buchanan's* comparison, the force exerted in turning a winch being made equal to the unit, the force in pumping will be	.61		
In ringing	1.36		
In rowing	1.43		
Allowing the accuracy of *Euler's* force, confirmed by *Schulze*, supposing a man's action to be a maximum when he walks $2\frac{1}{2}$ miles an hour, we have $7\frac{1}{2}$ for his greatest velocity, .04 $(7\frac{1}{2}-v)^2$ for the force exerted with any other velocity, and .0160 $(7\frac{1}{2}-v)^2$ for the action in each case: thus, when the velocity is one mile an hour, the action is	.676		
When two miles	.964		
Three	.972		
Four	.784		
And when five	.5		

"And the force in a state of rest becomes $2\frac{1}{4}$, or about 70lb.; with a velocity of two miles, 36lb.; with three, 24lb.; and with four, 15lb.

"It is obvious, that in the extreme cases this formula is inaccurate, but for moderate velocities, it is probably a toler able approximation.

"Coulomb makes the maximum of effect wher a man, weighing 70 kilogrammes, carries a weight of 53lb. up stairs; but this appears to be too great a load; he considers 145 kilogrammes as the greatest weight that can be raised. He observes, that in Martinique, where the thermometer is seldom below 68°, the labour of Europeans is reduced to one half.

"Harriot asserts that his pump, with a horizontal motion, enables a man to do one-third more work than the common pump, with a vertical motion.

"Porters carry from 200lb. to 300lb. at the rate of three miles an hour; chairmen walk four miles an hour with a load of 150lb. each; and it is said that in Turkey, there are porters, who, by stooping forward, carry from 700 to 900lb. placed very low on their backs.

"The most advantageous weight for a man of common strength to carry horizontally, is 112lb.; or, if he returns unladen, 135lb. With wheel-barrows, men will do half as much more work as with hods. *Coulomb.*

"*Performance of Men by Machines.*

	Force.	Continuation.	Days' Work.
A man raised by a rope and pulley, 25lb. (French) 220 feet (French) in 145″. *Amontons*	.436	145	
A man can raise, by a good common pump, a hogshead of water 10 feet high in 1′, for a whole day. *Desaguliers*	.875		.875
By the mercurial pump, or another good pump, a man may raise a hogshead 18 or 20 feet in 1′, for 1 or 2 minutes	1.61	1′	
In a pile engine, $55\frac{1}{2}$lb. (French) were raised 1 foot (French) in 1″, for 5 hours a day, by a rope drawn horizontally. *Coulomb*	.64	5^h	.82
Robison says, that a feeble old man raised 7 cubic feet of water $11\frac{1}{2}$ feet in 1′, for 8 or 10 hours a day, by walking backwards and forwards on a lever. *Enc. Br*	.837	9^h	.753
A young man, weighing 135lb. and carrying 30lb. raised $9\frac{1}{4}$ cubic feet $11\frac{1}{2}$ feet high, for 10 hours a day, without fatigue. *Robison*	1.106	10^h	1.106
Wynne's machine enables a man to raise a hogshead 20 feet in 1 minute. *Young*	1.75	1′	
"*Force of Horses.*			
Two horses attached to a plough on moderate ground, exerted each a force of 150 (French.) *Amontons.* We may suppose that they went a little more than two miles an hour for 8 hours	5.4	8′	4.32
A horse draws with the greatest advantage when the line of direction is level with his breast; and he can draw with a force of 200lb. $2\frac{1}{2}$ miles an hour, for 8 hours in the day	7.33	8^h	5.87
With a force of 240, only 6 hours. On a carriage, indeed, where friction alone is to be overcome, a middling horse will draw 1000lb. *Desaguliers*	8.8	6^h	5.28
The mean draught of four horses was 36 myriogrammes each, or 794lb. *Regnier.* This must have been momentary. Supposing the velocity 2 feet in 1″, the action would have been	15.88	1″	
By means of pumps, a horse can raise 250 hogsheads of water 10 feet high, in an hour. *Smeaton's Reports*	3.64	1^h	

"A horse can in general draw no more up a steep hill than three men can carry, that is, from 450lb. to 750lb.; but a strong horse can draw 2000lb. up a steep hill, that is but short. The worst way of applying the force of a horse, is to make him carry or draw up-hill; for, if the hill be steep, three men will do more than a horse, each man climbing up faster with a burden of 100lb. weight, than a horse that is loaded with 300lb., a difference arising from the position of the parts of the human body being better adapted to climbing than those of a horse.

"On the other hand, the best way of applying the force of a horse, is in an horizontal direction, wherein a man can exert least force: thus a man, weighing 140lb., and drawing a boat along by means of a rope coming over his shoulders, cannot draw above 27lb., or exert above one-seventh part of the force of a horse employed to the same purpose.

"The very best and most effectual posture in a man, is that of rowing; wherein he not only acts with more muscles at once for overcoming the resistance, than in any other position; but as he pulls backwards, the weight of his body assists by way of lever.—*Desaguliers.*

"The diameter of a walk for a horse-mill, ought to be at least 25 or 30 feet.—*Desaguliers.*

"Some horses have carried 650lb. or 700lb. seven or eight miles without resting, as their ordinary work; and a horse at Stourbridge carried 11cwt. of iron, or 1232lb. for eight miles.—*Desaguliers, Exp. Philos.* vol. i.

"*Work of Mules.*	Force.	Contin-uation.	Day's Work.
Cazanel says, that a mule works in the West Indies two hours, out of about 18, with a force of about 150lb. walking 3 feet in a second....................	4.4	2h 40′	1.2

Force, *Inanimate.* "According to M. Coulomb, a windmill with four sails, measuring 66 feet (French) from one extremity to that of the opposite sail, and 6 feet wide, or a little more, is capable of raising 1000lb. (French) 218 feet in 1′ and of working on an average 8 hours in a day. This is equivalent to the work of 34 men, as it has been above estimated, 25 square feet of canvass performing about the daily work of a man.

"Robison says, that 1 cwt. of coals burned in a steam-engine will raise at least 20,000 cubic feet of water 24 feet high; this is equivalent to the daily labour of 8.32 men. A steam-engine in London, with a 24-inch cylinder, does the work of 72 horses, and consumes a chaldron of coals in a day; each bushel being equivalent to two horses, and each square inch of the cylinder performing nearly the work of a man.

"If we calculate the quantity of motion produced by gunpowder, we shall find that this agent, though extremely convenient, is far more expensive than human labour; but the advantage of gunpowder consists in the great rarity of the acting substance. A spring or a bow can only act with a moderate velocity, on account of its own weight. The air of the atmosphere, however compressed, could not flow into a vacuum with a velocity so great as 1,500 feet in a second. Hydrogen gas might move more rapidly, but the elastic substance produced by gunpowder is capable of propelling a very heavy cannon-ball with much greater velocity.

"It is said, that nine tons of water, falling 10 feet, will grind and dress a bushel of wheat; consequently a man might do the same in 33′ 36″."

FORE-FRONT, the principal or front entrance of a building.

FORE-GROUND, that part of the field of a picture which is nearest the observer.

FORE-PLANE, in carpentry and joinery, the first plane used after the saw or axe. See Tools.

FORE-SHORTEN, in perspective, the diminution which the representation of the side or part of a body has in one of its dimensions, compared with the other, occasioned by the obliquity of the corresponding side or part of the original body to the plane of projection.

FOREYN, an ancient term signifying a cesspool or drain.

FORGE, a smith's furnace.

FORM (from the Latin, *forma*) the external appearance, or the disposition of the surfaces of a body; in which sense it is synonymous with Figure, which see.

Form, in joinery, the long seats or benches in the choirs of churches, for the priests, canons, prebendaries, &c. to sit on. Du Cange supposes the name derived from the backs of the seats being anciently enriched with figures of painting and sculpture, called in Latin *formæ et typi.*

FORMERETS, (from the French) the arches which are next the wall in Gothic groins; these are only half the thickness of those that divide the vault into compartments.

FORM-PIECES, the lower ends of the mullions of windows which are worked upon the sills. The same as Stool-pieces.

FORT, (Latin, *fortis* strong) a fortified building; a building strengthened by artificial means. The term is usually applied to small detached buildings.

FORTALICE, a small castle.

FORNIX, (Latin) an arch or vault. *See* Arch, and Vault.

FORUM, (Latin) in Roman antiquity, the market-place for transacting the business of the public revenue, bankers, merchants, &c. The following description of it is given by Vitruvius:

"The Greeks made their forums square, with large double porticos, the columns close together, and adorned with stone or marble epistyliums, making ambulatories in the upper stories: but the cities of Italy follow not the same method; because, by ancient custom, the shows of gladiators are usually given in the forum. For this reason the intercolumns around the area are made wider; and in the surrounding porticos the shops of the bankers are disposed, with galleries in the upper floors, properly adapted for the use and management of the public revenue.

"The magnitude of the forum should be suitable to the number of the people, that it may not be too small for use, nor on account of the scarcity of people, appear too large. The proportion is so determined, that the length being divided into three parts, two are given to the breadth; for thus it will be of an oblong form, and convenient for the use of the shows.

"The upper columns are made a fourth part less than the lower; because, as the inferior sustains the greater weight, it should be stronger than the superior: also because it is proper to imitate nature; for in straight-growing trees, such as the fir, cypress, and pine, there are none thicker at the top than at the root; and as they grow in height, they gradually diminish to the uppermost point. Following therefore the example of nature, it is proper that the superior should be made less than the inferior, both in height and thickness.

"The basilica should be joined to the forum on the warmest side, that the negociants may confer together, without being incommoded by the weather. The breadth is not made less than the third, nor more than the half of the length, unless the

the nature of the place opposes the proportion, and obliges the symmetry to be different. But if the basilica have too much length, chalcidicæ are made at the ends, as they are in the basilica of Julia Aquiliana. The columns of the basilica are made as high as the porticus is broad. The porticus is the third part of the space in the middle. The upper columns are less than the lower, as above written. The pluteum, which is between the upper columns, should also be made a fourth part less than the same columns, that those who walk in the floor above may not be seen by the negociators below. The epistylium, zophorus, and coronæ, are proportioned to the columns in the manner explained in the third book.

"Nor will basilicas of the kind of that at the colony of Julia of Fanum, which I designed and conducted, have less dignity and beauty; the proportions and symmetry of which are as follow: The middle testudo between the columns is 120 feet long, and 60 feet broad. The porticus around the testudo, between the walls and columns, is 20 feet broad. The height of the continued columns, including their capitals, is 50 feet, and the thickness 5, having behind them parastatæ 20 feet high, $2\frac{1}{2}$ feet broad, and $1\frac{1}{2}$ foot thick, which sustain the beams that bear the floors of the porticos. Above these are other parastatæ 18 feet high, 2 feet broad, and 1 foot thick, which also receives beams sustaining the canthers of the porticos, which are laid below the roof of the testudo: the remaining space that is left between the beams which lie over the parastatæ, and those which lie over the columns, is left open in the intercolumns, in order to give light. The columns in the breadth of the testudo, including those of the angles to the right and left, are four; and in the length, on that side which is next the forum, including the same angle-columns, eight. On the other side, there are but six columns, including those of the angles, because the middle two on this side are omitted, that they may not obstruct the view of the pronaos of the temple of Augustus, which is situated in the middle of the side-wall of the basilica, looking towards the centre of the forum and temple of Jupiter. The tribunal in this building is formed in the figure of a hemicycle: the extent of this hemicycle in front is 46 feet, and the recess of the curvature inward 15 feet, so that those who attend the magistrate obstruct not the negociants in the basilica.

"Upon the columns, the compacted beams, made from three timbers of two feet are placed around; and those from the third columns which are in the interior part, are returned to the antæ that project from the pronaos, and on the right and left touch the hemicycle.

"Upon the beams, perpendicularly to the capitals, the pilæ are placed, three feet high and four feet broad, on every side. Over these, other beams, well wrought from two timbers, of two feet, are placed around; upon which, the transtræ and capreols, being placed coincident with the zophorus, antæ, and walls of the pronaos, sustain one culmen the whole length of the basilica, and another transversely from the middle over the pronaos of the temple: so that it causes a double disposition of the fastigium, and gives a handsome appearance to the roof on the outside, and to the lofty testudo within. Also, the omission of the ornaments of the epistylium, and of the upper columns and plutei, diminishes the labour of the work, and saves great part of the expense. The columns likewise being carried in one continued height up to the beams of the testudo, increases the magnificence and dignity of the work."

Forum is also used for any place in which the governor of a province convened the people, to give judgment according to the course of the law.

Forum also meant a public standing-place in the city of Rome, where causes were judicially tried, and orations delivered to the people.

The Roman foræ were of two kinds—Fora Civilia and Venalia; the former were for law and political affairs, the latter for the purposes of trade. Of the Fora Civilia, there were at first only three, viz., Romanum, Julianum, and Augustum; but their number was afterwards increased to six, by the addition of the transitorium, called also palladium, the Trajanum, and Salusti.

The first and most eminent of these was the *forum Romanum*, called also *forum vetus*. In the time of Romulus, this forum was only a large open space, without buildings or other ornament. It was first enclosed by Hostilius, adorned with porticos by Tarquin the Elder, and at length, by the additions of succeeding kings, consuls, and magistrates, it became one of the most elegant and noble places in the world. It was called *forum Romanum*, or simply *forum*, by way of eminence, on account of its antiquity, in comparison with the other fora, and from its more general use in public affairs. It was also called *forum Latinum*, *forum magnum*, and *old forum*. The comitium, used sometimes for holding the comitia, was a part of this forum, in which stood the *rostrum*, a sort of pulpit, adorned with the beaks of ships taken in a sea-fight from the inhabitants of Antium. In this the causes were pleaded, orations were made, and panegyrics were delivered on the merits of the dead.

A very beautiful restored view of the Forum Romanum was made by Mr. C. R. Cockerell, and a reduced view was engraved and published, with his permission, in the second volume of the "Pompeii," published by the Society for the Diffusion of Useful Knowledge, to which we refer our readers for an accurate notion of the splendour of the accumulated architecture of the Forum and the Capitol, and its vicinity.

The Julian forum, called also *Cæsar's forum*, was built by Julius Cæsar with the spoils taken in the Gallic war. Its area alone, according to Suetonius, cost 100,000 sesterces and Dio affirms, that it much exceeded the Roman forum.

Augustus's forum, built by Octavius Cæsar, was reckoned by Pliny among the wonders of the city. The most remarkable curiosity it presented was the statues in the two porticos on each side of the main building. In one were all the Latin kings, beginning with Æneas. In the other, all the kings of Rome, beginning with Romulus; most of the eminent persons in the commonwealth, and Augustus himself among the rest, with an inscription upon the pedestal of every statue, descriptive of the chief actions and exploits of the person it represented. This forum was restored by the emperor Adrian.

Nerva's forum was begun by Domitian, but finished and named by the emperor Nerva. In this forum Alexander Severus set up the statues of such of the emperors as had been deified, in imitation of what Augustus had done in his forum. This forum was called *transitorium*, because it lay very convenient as a passage to the others, and *palladium*, from a statue of Minerva which was set up in it. Scarcely anything remains of this forum except a decayed arch, which the Italians, by a strange corruption, call *Noah's ark*, instead of *Nerva's arch*.

Trajan's forum was built by the emperor Trajan with the produce of the spoils taken in his wars. The porticos, which were exceedingly beautiful and magnificent, were covered with brass, and supported by pillars of more than ordinary size, and of exquisite workmanship.

The forum of Pompeii, which was constructed in the Greek style, cannot, however, be altogether considered, if we are guided by the authority of Vitruvius, a truly Greek

Agora, which this author states was to be made square in form. It has, however, many Greek features. The Pompeian forum is of an oblong shape, surrounded on three sides with rows of columns, forming, with the advanced columns of the various buildings, a colonnade or ambulatory ; above this there was a second, if we may judge from the remains of stairs at several places at the back of the colonnade. The fourth side of the forum is enclosed with two arches placed on each side of a large hypæthral temple, called the temple of Jupiter. On the west side are the prisons and the granary, before these, and the temple of Venus, and the Basilica, is an enclosed court. On the narrow side, opposite the temple of Jupiter, are three buildings, generally considered to be the Curiæ and Ærarium. On the east side is an enclosure, (the use of which has not been determined,) the Chalcidicum, the temple of Mercury, the Senaculum, and a building supposed to be a large eating-house, generally known by the name of the Pantheon, in front of which are the Tabernæ Argentariæ. The enclosed area of the forum was paved with large square pieces of marble, and the sides of the area were adorned with statues. Opposite the Curiæ, and a short way from them, is a small triumphal arch. The forum was closed at night with iron-barred gates, and it does not appear that chariots were admitted into it, as the pavement of the streets terminates at the back of the colonnade. The columns of the ambulatory are of the Greek Doric order, and were being restored in the same style, though with better materials, at the time the city was destroyed. The columns were aræostyle, and the architraves were most probably of wood, as we may infer from their being destroyed, while the frieze and cornice of stone remain.

The forum of Constantinople was erected by Constantine when he established the city on the commanding eminence of the second hill, where he pitched his tent during the siege and conquest of Byzantium. The edifice was of an elliptic form ; the two opposite entrances formed triumphal arches ; the porticos on every side were filled with statues, and the centre of the edifice was occupied by a lofty column, of which only a mutilated fragment is now left, and is degraded by the appellation of *the burnt pillar*. This column was erected on a pedestal of white marble, 20 feet high. It was composed of 10 pieces of porphyry, each of which measured about 10 feet in height, and about 33 in circumference. On the summit of the pillar, above 120 feet from the ground, stood a colossal statue of Apollo, of bronze, which had been transported hither from Athens, or from the town of Phrygia, and was supposed to be the work of Phidias. The artist had represented the god of day, or, as it was afterwards interpreted, the emperor Constantine himself, with a sceptre in his right hand, the globe of the world in his left, and a crown of rays glittering on his head. This statue was thrown down in the reign of Alexis Comnenus.

FOSSE, a trench or ditch excavated round a fortified place, to secure it from attack.

FOSSES D'AISANCES, a term used to designate the cesspools of Paris. These cesspools are constructed of materials sufficiently impermeable to filtration, so that the matter contained in them shall not penetrate through the walls, to the injury of the adjoining property. So strictly is this condition observed, that any infiltration to a neighbour's premises, according to the French law, gives a title to damages, and the architect and builder are held responsible for ten years, not only to the proprietor, but also to the neighbours, should any nuisance arise from imperfect execution of the work.

The *Fosses d'Aisances* are usually made about 10 feet long by about 5 feet 7 inches wide, and 5 feet in height to the springing of the semi-circular head. The material employed in their construction, has of late years been *meulière* or millstone, bedded in mortar made of lime and cement ; the inside being well pointed, and rendered throughout with the same. These cesspools are cleansed out when necessary, under the inspection and by the authority of the board of health of the city ; the carts employed, as well as all the *materiel* of the nightmen, being under the same surveillance. The work is done between ten o'clock at night and six o'clock in the morning. The contents of the cesspools are generally sufficiently fluid to allow of their extraction by pumps ; but when this is not the case, they are conveyed from below in small iron vessels ; and great care is taken to prevent, as much as possible, the escape of the noxious effluvia during the operations. When the soil is pumped into carts, a small furnace is placed over the bung-hole of the cart, to burn the gas as it rises ; and directly the cart is filled, the bung is plastered over. The lids of the vessels used to remove the more solid matter, are also plastered over in a similar manner, before they are brought out of the cesspools. For a fuller description of the Fosses d'Aisances, *see* SEWER, SEWERAGE.

FOUNDATION, (from the French) the trench or trenches excavated in the ground, in order to rest an edifice firmly upon its base. The word also means the superstructure of a stone or brick wall under the lowest floor of a building, contained within the trenches.

Foundations, according to Palladio, ought to be twice as thick as the walls to be raised upon them, so that both the quality of the earth and the greatness of the building are to be regarded, making the foundation larger in a soft and loose ground, or where there is a great weight to be supported. The plane of the trench must be as level as possible, so that the weight may press equally, and not incline more on one side than the other. For this reason the ancients were accustomed to pave the plane with Tivertine ; but the moderns most commonly lay planks or beams to build on. The foundations ought to diminish in width as they rise ; but in such a manner that the middle of the wall above may fall plumb with the middle of the lowest part; this must also be observed in the diminution of walls above ground, because by that means the building becomes much stronger than by making the diminution any other way.

The various methods of treating the building of a foundation, according to the heterogeneous texture or uniformity of the ground, as may happen in the excavation, will be found under BRICKLAYING. Under the same head also will be found ample directions for making a foundation of CONCRETE, as now so generally used by builders. But should the foundation prove unsound, or of that character that dependence cannot be placed upon it, recourse must be had to piling, in the following manner. Good sound piles must be prepared, of such dimensions, that their thickness may be about a twelfth part of their length ; the distances at which those piles should be disposed, and the momentum requisite to drive them, will depend on the nature of the building to be erected ; and the weight they will have to bear ; the weight of the ram ought not to be more than sufficient for driving the piles, as the heavier the ram, the greater the number of men required to work it, and consequently the greater the expense. When the piling is completed, so as to be sufficient for supporting the intended structure, some builders lay a level row of cross bearers, called *sleepers*, ram the interstices with stone or brick up to the level of their faces, and then plank them over. This planking, however, may be dispensed with, if the piling be sufficiently attended to, and the expense of the foundation will thus be materially lessened. Timber

should not be used with its thickness standing vertical, as it is liable to shrink, which will make the building crack or split at the junctions with the return parts.

Where the ground is not very soft, and where the wall is to be supported upon narrow piers, a piece of timber, or balk, is sometimes slit in halves, and those are either laid immediately at the bottom, or at the height of two or three courses from the bottom of the wall; which will frequently prevent settlements when the wall is to be so supported.

Forced earth, or made ground, remains unfit for the foundation of a wall, for a considerable time.

The breadth of a substructure should be proportioned to the weight of the superstructure, and to the softness of the ground on which it rests; if the texture of the ground is supposed to be constant, and the materials of the same specific gravity, the breadth of the foundation will be as the area of the vertical section passing through the line on which the breadth is measured; thus, for example, Suppose a wall 40 feet high, 2 feet thick, to have a sufficient foundation of 3 feet in breadth, what should be the breadth of the foundation of a wall 60 feet high, $2\frac{1}{2}$ feet thick? By proportion, it will be $40 \times 2 : 3 :: 60 \times 2\frac{1}{2}$: the answer$=5\frac{5}{8}$ feet. This calculation will give the breadth of the foundation of the required wall, equal to the breadth of the insisting wall itself; when the height of the required wall is equal to the ratio, which is the first term $(40 \times 2 = 80)$ divided by the second term $(3) = \frac{80}{3} = 26\frac{2}{3}$. Thus a wall of $26\frac{2}{3}$ feet would have the breadth of its foundation equal to its thickness above the foundation, and less than $26\frac{2}{3}$ feet would have a thinner foundation than even the superstructure. But though the calculation in this case gives the foundation less in breadth than the thickness of its superstructure, it must be considered that it only calculates the true breadth of the surface that should be opposed to the ground, in order to prevent the wall from penetrating by its weight: though the rule gives all the width that is necessary, on account of the weight of the insisting wall, yet the breadth of the footing should always be greater than that of the superstructure; as it will stand more firmly on its base when affected by lateral pressure, and be less liable to rock by the blowing of heavy winds. The least breadth that is commonly given to the bottom course of stone walls is one foot thicker than the superstructure. In damp situations, the superstructure should always be separated from the substructure by layers of lead, tarred paper, &c. Slate also may be used with advantage for such purposes.

FOUNTAIN, (from the French *fontaine*,) literally signifies a spring or issuing of water from the earth, but the word is also applied to a machine or artificial contrivance by which water is made to spout or dart up, called by the French a *jet d'eau*. There are various kinds of artificial fountains, but they are all formed by some description of pressure on the water, that is, the water of the fountain is made to spout up, by the weight of a head of water; by the pressure arising from the spring and elasticity of condensed air, or by machinery.

FOX-TAIL WEDGING, a method of fastening a tenon in a mortise, by splitting the end of the tenon and inserting a projecting wedge, then entering the tenon into the mortise, and driving it home; the bottom of the mortise will then resist the wedge, and force it farther into the tenon, which will expand in width, so as not only to fill the cavity at the bottom, but be firmly compressed by the sides of the mortise.

FRACTION, in arithmetic and algebra, is a part or parts of something considered as a unit or integer. Fractions are distinguished into vulgar fractions and decimal fractions. Vulgar fractions consist of two parts or quantities written one over the other, thus $\frac{2}{3}$, $\frac{3}{4}$, &c.; the quantity above the line is called the numerator, and that below the line the denominator. *See Decimal.*

FRAME, in carpentry, a combination of timber-work, composed of one or more triangular compartments, or of a mixture of triangles and quadrilaterals, the timbers being either joined together by joggles, or by being halved or let into each other.

Three pieces of timber are the least number that can constitute a frame, for the same reason that less than three straight lines cannot constitute a space. *See* the articles FLOORING, NAKED-FLOORING, PARTITION, TRUSS, and TRUSS-PARTITION.

FRAME, in joinery, an assemblage of various pieces of wood-work, forming certain compartments, according to the design, surrounding panels of wood, which are inserted in grooves made in every edge of each compartment of the frame, and thus filling up the interstices. This mode is a substitute for a board, which could not be procured in one breadth; and even if such a board could be obtained, framing would be preferable, as being much lighter, stronger, and less liable to warp. The stiffness of a frame in carpentry depends chiefly upon the triangles in its composition; but a frame in joinery depends upon the inflexibility of the joints, taking every two pieces separately, by which each joint is formed.

FRAMING, of a house, all the timber-work, *viz.*, the carcase-flooring, partitioning, roofing, ceiling, beams, ashlering, &c.

FRANKING, in sash-making, cutting a small excavation on the side of a bar for the reception of the transverse bar, so that no more of the wood be cut away than what is sufficient to show a mitre when the bars are joined to each other; by this means, the strength is impaired only in the smallest possible degree.

FRATERY, OR FRATER-HOUSE, the dining-hall of monastic buildings, otherwise termed REFECTORY.

FREEMASON, in ancient times was the term applied to a person supposed to be skilled in the art of building, more particularly in ecclesiastical construction. A freemason travelled from place to place, and by his learning in the science, and his taste in the construction of edifices, executed works celebrated for beauty and grandeur. In the present day the word is identified with the society of Freemasons, whose various ramifications are said to extend throughout the known world.

FREEDSTOOL, FRIDSTOOL, OR FRITHSTOOL, a seat placed at the east of some churches, near the altar, for those who sought the privilege of sanctuary. They were usually of stone, specimens of them in this material are still existing at Beverley and Hexham.

FREE-STONE. *See* STONE.

FREE-STUFF, that which works easily in the operation of planing, without tearing.

FREEZE, a part of the entablature of an order; more correctly spelt FRIEZE, which see.

FRENCH CASEMENTS, windows turning upon two vertical edges attached to the jambs, which when shut lap together upon the other two parallel edges, and are fastened by means of long bolts extending their whole height.

French casements are made in the form of the old English windows, the two meeting styles, which lap together, forming a munnion about four inches in breadth. The lower part only is moveable, the upper is fixed, and has a corresponding

munnion, the lower rail of the fixed part and upper rail of the moveable part forming a transom.

FRESCO PAINTING, a peculiar mode of painting, performed by employing colours mixed and ground with water upon a stucco, or plaster, sufficiently fresh and wet to imbibe and embody the colours with itself. The term *fresco*, as applied to painting, is said to have been adopted because the practice of it is used in the open air; *andare al fresco* signifying "to take the air," or "walk abroad in the air:" but it seems more probable that another meaning of the word *fresco* has given rise to this particular adoption of it, viz., new, or fresh, relative to the state of the plaster on which it is wrought. Vitruvius (lib. vii. cap. 4.) calls it *udo tectorio.* It is very ancient, having been practised in the earliest ages of Greece and Rome.

The theory of the art of painting extends its principles to all modes of execution, because theoretic rules are drawn from nature, which is the object of all imitation, and are independent of the means employed in producing the intended effect. We propose, therefore, in this place, only to treat of the mode of execution, and of the materials employed in fresco painting; such observations as the recent revival of the art has rendered necessary, being deferred till after our description of the practice.

Previously to the commencement of a painting in fresco, it is necessary that a careful examination should be made of the fitness of the place to receive it. The artist must assure himself, therefore, in the first place, of the perfect construction of the walls, or ceilings, on which he intends to employ his genius, and entrust his reputation: above all, he must be careful to make it secure from damp.

Satisfied with the construction of the wall, it is then necessary the artist should see to the proper management of the first layer of plaster with which it is covered. The materials employed for building in different countries will vary according to the nature of those most easy to be obtained: and therefore it will, of course, be necessary to adopt means for rendering those not perfectly proper in themselves to receive fresco painting, more so by artificial means. Brick is certainly the one best calculated to hold the plaster perfectly; both on account of its absorbing quality, and from the smallness of the size of the bricks causing a number of interstices between them; which irregularity in the surface greatly assists in retaining the plaster in adherence. A wall built of rough stones full of holes may also be relied upon as a good foundation for fresco; but if, instead of that, it be constructed of smooth or polished stones, it will then be necessary to render it uneven by making holes in it, fastening nails, and small wedges of wood, to hold the plaster together, and prevent its falling off. These precautions are of the utmost consequence to prevent its bending or cracking, which the least alteration that happens to the materials, or even a change of weather, producing alternately wet or dry, may occasion.

The first layer of plaster may be composed of well-washed chalk made into a cement with pounded brick, or river sand; the last is better, being rather the coarsest, and producing thereby a roughness of surface which will better retain the second coat.

Tarras, composed of pounded sea-sand and chalk or lime, would perhaps be better still. The ancients had certainly a better compost for this purpose than that at present known; if we may judge from that which still covers many of their buildings; particularly the aqueduct they constructed near Naples, and the walls of the ruins of Herculaneum.

Before the second layer is given, the first must be perfectly dry, on account of a disagreeable and noxious vapour which issues from the lime in drying; but when it is so, and you proceed to give it the second coating, upon which the painting is done, it must be wetted with water, that the two may more completely incorporate. This layer, which requires to be more carefully prepared than the first, is made by mixing river-sand of an even and fine grain with chalk, which has been burnt several months before, and exposed to the air, as by that means the artist may be more sure of its general decomposition and freedom from stony parts.

It requires considerable skill in the person who prepares this ground, to lay it perfectly even, and he must be very careful in judging of the quantity proper to be laid on at once. This ought not to be more than the painter can cover and completely finish in a day; and it requires great skill and activity in spreading, to clean it from lumps and polish it evenly, so as to receive the painting with the promptitude requisite to leave the artist as much time as possible. The painter, however, should himself superintend this part of the process, for he alone can judge properly as to the rapidity with which he can work, or the advantages he may make of accidental occurrences.

The operation of laying on the ground is performed with a trowel, and in doing this, care must be taken to clean it properly, that the surface may be even, particularly in those parts most exposed to view. The mason's labour is finished by his polishing the surface to receive the painting; this is done by applying a piece of paper on the face of the wall, and passing the trowel over it. It is very necessary that this should be well done, for small inequalities in the surface might, in certain views, produce great irregularities in the drawing of the work.

When the second ground is thus prepared, cleaned, and polished, in the quantity, and on the part of the wall which the artist requires, he begins to trace his design upon it, and proceeds to the colouring of it; completely covering the quantity prepared, and finishing so much of the picture in the course of the day, in such a manner that he may not have occasion to re-touch it when the ground is dry. This is the characteristic peculiarity of painting in fresco, which, by this mode of operation, is incorporated with the mortar, and drying along with it, becomes extremely durable, and brightens in its tones and colour as it dries.

From the necessity there is in the progress of this style of art, that it should be executed with rapidity, and from the impossibility of retouching it without injuring the purity of the work; the artist, unless he be endowed with very extraordinary powers of imagination and execution indeed, is obliged to prepare a finished sketch of the subject, wrought to its proper hue and tone of colour, and so well digested, that there may be no necessity for making any essential alterations in the design. This, which is a very useful mode of proceeding in all historic works of painting, is absolutely indispensable in fresco, to those who are not determined to give the rein to their ideas, and leave as perfect whatever may first present itself. There is no beginning in this, by drawing the whole of the parts at one time, and correcting them at leisure, as is the custom in oil painting, where the artist may proceed to work without a sketch. Here all that is begun in the morning must be completed by the evening; and that almost without cessation of labour, while the plaster is wet; and not only completed in form, but also (a difficult, nay, almost impossible task, without a well-prepared sketch,) must be performed, viz., the part done in this short time must have so perfect an accordance with what follows, or has preceded of the work, that when the whole is finished, it may appear as if it had been executed at once, or in the usual mode, with sufficient time given to harmonize the various forms and tones of colour. Instead of proceeding by slow

degrees to illuminate the objects, and increase the vividness of the colours, in a manner somewhat similar to the progress of nature in the rising day, till at last it shines with all its intended effect, which is the course of painting in oil; the artist working in fresco must at once rush into broad daylight; at once give all the force in light and shade and colour, which the nature of his subject requires. This, be it observed also, must be without the assistance (at least in the commencement) of contrast to regulate his eye; and therefore may be considered almost impossible, as we have before said, unless he be assisted by a well-digested and finished sketch.

The sketch being completed, the next process is to prepare a cartoon or drawing of the design on paper pasted together to the size of the intended fresco. This cartoon should be perfected in the outline to save time, and the artist has then nothing to do but to trace the line of the figures or other objects which the design may be composed of, on to the plaster, by either pricking with a pin through the paper, or by passing a hard point over the lines of the cartoon. By this means he saves himself the trouble of drawing the figures, and also the time which would be required for doing it, and proceeds at once to the painting; to facilitate the execution, and ensure the success of which, several precautions are requisite.

The colours being ground fine in water, and a sufficient quantity of the tints most likely to be employed prepared, they should be arranged in pots or basons, and several pallettes with raised edges should be ready at hand to work from, and assist in compounding the varieties of hues necessary for producing brilliancy and harmony. A few pieces of tile or brick, or of any absorbent stone, should also be provided, to prove the tints upon, because all colours ground in water become much lighter when dry, than they appear when wet. To be certain therefore of their hue, before he begins to use them on the picture, and to avoid the trouble and necessity of much changing or labouring them, (as the painters term the blending of colours,) the artist should apply some of each tint with his brush to the dry brick, &c., which, absorbing the water, the colours immediately appear very nearly of the same hue they will be of when the fresco is dry. Hence he may proceed with great security in his work, and is sure to have it much more fresh and vigorous in effect, than it would be if much labour had been employed to obtain the tone on the wall.

It will be requisite also to have at hand a vase or bason of water, or a wet sponge, and to take care not to begin to paint till the layer of mortar is hard enough to resist the impression of the finger: otherwise the colours would spread upon it, and prevent all possibility of neatness or clearness in the execution, which should be effected with great rapidity and lightness of hand.

With respect to the colours employed in fresco, they are fewer in number than those which may be used in oil painting, on account of the combined action of the lime and the air upon the component parts of many of the latter. Those most generally in use are the following, viz.:—

Lime-White.—This, when made of well-washed burnt chalk or lime, is the best and most simple white that can be used; it mixes freely with all the other colours, and works in itself with a full body. The preparation of it requires that the chalk should be slacked a twelvemonth before it is used, or at least, six months. It should then be dissolved in common water, and poured carefully off, (after letting it fall some short time,) into a vessel to settle.

Another white is made by mixing one-third of white marble powder with two-thirds of chalk; but it must be used with caution, as it is apt to change. If the proportion of marble dust be too strong for the chalk, it will become black. The artist will therefore do well to confine himself to chalk white, provided it has been well prepared, and kept a long time. As this, however, has frequently been used, we deemed it proper to be mentioned, that artists may, if they choose, make experiments upon its nature, and endeavour, if they find any peculiarly valuable quality in it, to ensure its continuance in clearness and perfection.

Egg-shell White.—There is also a third white, made of egg-shells, which, though it has not the full texture of the chalk, is yet very clear and good for use in fresco. It is made by boiling egg-shells in water with a little quick-lime. They are then put into a pot, and washed with pure water. Then pounded fine, washed again till no tint is given to the water, and then ground by the muller and stone to the degree fit for use; it is afterwards formed into little cakes, which are dried in the sun. Care must be taken not to let the powder of the shells remain too long in the same water, as it will exhale a fetid vapour almost insupportable, which cannot be dissipated but by roasting it in a close vessel, well luted.

Red—produced by burnt vitriol, in colour approaching to Indian red, and ground in spirits of wine, acts well with the lime, resists the action of the air, and mixes cleanly with the other colours. This forms an excellent preparation to receive the bright red of cinnabar or vermilion, when the whole wall is covered.

Colours of earthy textures, such as the ochres, whether burnt or not burnt, umber, both raw and burnt, Spanish red, Verd de Verona, Venice black, and blue black, made by bruising vine-stalks, or shells of peach-nuts, are all excellent for the purposes of fresco painting.

Blues.—The best is the ultramarine, as it never suffers any change. Smalt or enamel blue is good as to preserving its tone, and, if used early in the work, will adhere; but if the ground should become too dry before it is used, it is apt not to incorporate strongly with it, but to come off on the least friction.

White lead, lake, verdigris, masticot, Naples yellow, the orpiments, and bone black, are all unfit for this purpose, being liable to change.

Painting in fresco, when carefully executed, is of all others the most durable, and therefore the most proper to be employed in adorning public buildings. The use of it for this purpose appears to be very ancient. Norden speaks of paintings in Egyptian palaces 80 feet high, which Winkelman quoting, concludes they were in fresco, from the description given of the prepared grounds, and of the manner in which the colours appear to have been used. And all the paintings found at Herculaneum, at Portici, and at Rome, of ancient date, are of the same materials. No other kind of painting would so effectually have resisted the action of the air for so great a length of time, and more particularly the excessive aridity which those of Herculaneum must have endured, being shut up entirely from the light, and amidst glowing embers from Vesuvius, emitting of course, especially at first, an intense heat around them. That, however, in one point of view, was favourable to the preservation of those that escaped its immediate action; for damp is the most powerful destroyer of them, against which no caution taken can make them too secure. In this case of Herculaneum, damp must have been effectually excluded, first by the heat of the ashes, and afterwards, as the stratum of those ashes was so thick, water from above could not penetrate so low as to the pictures, particularly after the upper part was covered with the close cake formed by the decomposed parts, on and near the surface.

In ordinary situations, the choice of materials is the most

important part, to secure the durability of the work, and particularly the greatest care is necessary in the preparation of the ground, and of the wall, to cause it to adhere.

Fresco painting has been chiefly employed in palaces, temples, and other public edifices. For large and important places no other kind of painting is so good. As the artist is obliged, from its nature, to proceed with rapidity in its production, it has necessarily more spirit and vigour in the execution, than paintings in oil, which may be repeated, and re-touched, as often as the artist fancies he can improve, or heighten their effect. In fresco there is not time to meddle, and disturb the freshness of the colour, or the fulness and freedom of the touch. But there can be no minute detail of forms, or extensive variety in the gradation of tints; the beauties of neatness, and delicacy of finishing, make no part of the excellencies of this branch of the art; it will not bear the close examination which well-finished pictures in oil do; there is something dry and rough in its appearance, unpleasing, to the common observer, on too close an inspection. It lacks the full rich sweetness of hue and texture which oil paintings possess; and though it has more freshness, and retains it, yet from the confined number of colours which can be employed in it, it is not equal to oil in the perfection of the imitation of nature.

Whoever seeks to be pleased with fresco painting, must learn justly to estimate the best, and not the most agreeable qualities of the art. Character, contour, expression, are within its powers; and are the points which the great artists who practice it, knowing its limits, will endeavour most to exhibit in their productions. Harmony of colouring, chiaro-oscuro, and the minute graces of execution, have never yet been rendered in it, or but very partially, in comparison with works in oil.

In the early part of the restoration of painting, a species of fresco was the only mode of practising the art, in use. A ground of chalk was prepared on tablets of wood, and the colours laid on it, ground and mixed in water only, or with some gluten soluble in it. The surface of the picture was afterwards covered with a varnish, to secure it from rubbing, and to give the tints more force and lustre.

"Fresco," observes a writer in *The Builder*, "was much used in England some four or five centuries since, in both ecclesiastical and civil structures of importance; the subjects being chiefly scriptural, with occasional deviations in favour of some legendary achievement, or as a pictorial record of some well-contested battle-field. With these bold and beautiful, but unresisting memorials of things sacred, and deeds that redounded to national glory, the fanatical spirit of the sixteenth and seventeenth centuries warred to extermination; neither the enrichments of the temple bestowed by the constant piety of our ancestors, nor the grateful reminiscences of heroic services of the state, were permitted to escape the devilries enacted by the factitious saints of the Puritan calendar: the frescoes perished; but better taste and better feelings have supervened, bidding fair to re-establish both the art itself, and the influential purposes to which it was anciently devoted."

The report of Mr. Barry on the proposed decorations of the interior of the new Houses of Parliament, is really a splendid programme of the association of sculpture and painting, upon an occasion too so fertile in appliances and means, that the principles of taste will, it is presumed, be developed in a manner to serve as examples for much of future time. With reference to painting, Mr. Barry says—"I would that the walls of the several halls, galleries, and corridors of approach, as well as the various public apartments throughout the building, should be decorated with paintings, having reference to events in the history of the country; and that these paintings should be placed in compartments formed by such a suitable arrangement of the architectural designs of the interior, as will best promote their effective union with the arts of sculpture and architecture. With this view, I should consider it to be of the utmost importance, that the paintings should be wholly free from gloss upon the surface, that they may be perfectly seen and fully understood from all points of view." "By paintings with surfaces free from gloss or glaze, we understand those wherein the colours employed are mixed in other mediums than oils or varnishes; and though fresco is not named, yet the magnitude of the surfaces to be covered, and the exception to those which are glazed, leads us to suppose that it is intended to revive this branch of art. Now, though the buildings to be thus adorned are progressing with considerable rapidity, much time must elapse before the interior is prepared to receive the embellishments contemplated; meanwhile, many will have their longings to share in these distinguished labours, and, generally, the revival will open a new field for talent, in which there will shortly be no want of encouragement for those who may have successfully cultivated it; so oblivious, however, has the art become, that we have repeatedly heard the question put as to its nature and mode of execution, and we think an explanation will be useful to many of our readers. Fresco is the art of painting in relievo with water-colours on fresh plaster; the amalgamation thus formed of the decorative material with the body to which it is applied, is endued with unchangeableness and permanence of a very extraordinary kind."

The appointment of "A Commission on the Fine Arts," especially directed "to inquire into the mode in which, by means of the interior decorations of the Palace of Westminster, the fine arts of this country can be most effectually improved," has no doubt led to the revival of the art of fresco-painting. The various reports of the commission contain a great deal of valuable information on the subject, and the employment of several artists to furnish specimens, has brought forward some beautiful examples of fresco-painting, and elicited talent that might, but for these circumstances, have been lost to the world. In addition to the encouragement thus afforded, the stimulus of a public competition, and the distribution of rewards to the successful candidates, Her Majesty and Prince Albert had given the advantage of their countenance to the art, by ordering the decoration of a summer-house in the gardens of Buckingham Palace with fresco paintings.

The idea of this experiment, for so it must be called, was surely a happy one; and not the less seasonable, that every one who had considered the subject (at least every one who understood it), felt that it was a method which presented peculiar difficulties to some of the ablest and most distinguished of our painters, whose habitual style of treatment of their subject and effect, had been precisely the reverse of what is required in fresco.

The application of fresco-painting, it may be observed, to the decoration of architecture demands the adaptation of parts to a whole; a preconcerted mode of treatment, in which the painting shall seem to be in union with the original design of the edifice; the harmonious combination of many minds, working under the direction of one mind, to one purpose; and with regard to the mechanical part of the process, it requires much thought and study in the preparation of the materials, and great care and precision, as well as great rapidity, in the execution.

The summer-house in question is very small, and is situated on an artificial mount in the gardens, overlooking the ornamental waters.

The entrance to the pavilion opens into the principal apartment, an octagon 15 feet 9 inches from side to side, and 14 feet 11 inches in height, to the centre of the vaulted ceiling. It is here, in eight lunettes at the foot of the vault, that the frescos from "Comus" appear, of which for the most part types have been exhibited in the rooms of the Royal Academy, by the respective artists. Over the entrance-door, is Stanfield's, illustrative of the following passage :—

> "Yet some there be that by due steps aspire
> To lay their just hands on that golden key,
> That opes the palace of Eternity.
> To such my errand is." COMUS, v. 12—17.

It is admirably transparent, and exhibits more power over the material than the majority of the works. Passing round with the sun, Mr. Uwin's follows, having for motto,

> "This is the place as well as I may guess,
> Whence even now the tumult of loud mirth
> Was rife."

Then comes Leslie: Ross follows. Eastlake's is over the mantlepiece; Maclise, Edwin Landseer, and Dyce, complete the eight. A copy of Mr. Maclise's work was in the Academy exhibition of 1845, and will be remembered by all. The lines illustrated are,

> "If virtue feeble were,
> Heaven itself would stoop to her."

Maclise shows the lady spell-bound in the marble chair, and displays much of his usual power. Mr. Landseer has found in the following lines an opportunity to exhibit his great skill in depicting the brute form :—

> "Their human countenance
> Th' express resemblance of the gods, is changed
> Into some brutish form of wolf or bear,
> Or ounce or tiger, hog or bearded goat."
> COMUS, v. 68—71.

Comus, surrounded by his crew, is terrified by the approach of the brothers, who appear behind in the act of rushing upon them. A bacchante, with a beautiful female form, and the head of a hound, has thrown herself in affright upon the arm of Comus. Other monsters, half brute, half human, in various attitudes of mad revelry—grovelling, bestial insensibility—confusion and terror—are seen round him; the pathetic, the poetical, the horrible, the grotesque, all wildly, strangely mingled. In the spandrils are two heads—a grinning ape, and a bear drinking.

Mr. Dyce winds up the illustrations with the presentation of the lady and her two brothers to their parents, who come forth to receive them, and he has produced what must be considered the best fresco, although perhaps wanting exactly the right sentiment.

The operations of the Fine Arts Commission seem tohave been highly satisfactory to the public in general, and, in respect to fresco-painting in particular, must be viewed as eminently successful. The exhibitions in Westminster Hall presented numerous paintings in this so long-disused art, of a highly artistic character; and the number of the prizes awarded, testify the great merit of the productions. The result of the preliminary competition was shown in the selection of several eminent artists to execute fresco-paintings in the new Palace of Westminster, and in the completion by those gentlemen of some of the finest pictures in this peculiar style, that have been seen since the days of the great painters of former times.

It would extend this article beyond the limit assigned to it, to give a full description of these admirable works; we must therefore confine ourselves to a list of the artists selected, and the subjects allotted to each for illustration.

The commissioners having decided that six compartments in the new House of Lords should be decorated with fresco-paintings, proceeded to allot the several works in the following manner :—

To Mr. Horsley, the subject of Religion.
To Mr. Thomas, the subject of Justice.
To Mr. Maclise, the subject of Chivalry.
To Mr. Dyce, the subject of the Baptism of Ethelbert.
To Mr. Redgrave, the subject of Prince Henry, afterwards Henry V., acknowledging the authority of Chief Justice Gascoigne.
And to Mr. Cope the subject of Edward the Black Prince receiving the Order of the Garter from Edward III.

In the Upper Waiting Hall, or, as it is to be called, the "Hall of Poets," the eight available panels which it affords, are appropriated to frescoes illustrative of Chaucer, Spenser, Milton, Shakspere, Dryden, Pope, Byron, and Scott. Such of these paintings as are finished at the time we write, are noble works, full of power and beauty, and fully justifying the commissioners in the selection they have made of the artists employed.

The principal works that have been produced in former times in fresco, are the series of biblical and evangelical historic pictures which adorn the walls and ceiling of the chapel of Sixtus V. at Rome, by M. A. Buonarotti; the chambers of the Vatican, known by the name of the Stanze of Raphael; which consist principally of religious histories interspersed with some legendary tales, relative to the popes; and the cupola of the duomo of Parma, or church of St. Giovanni in that city, by A. Correggio. It represents the Ascension of the Virgin, amidst a choir of angels, and with a number of figures of saints below regarding it. One beautiful and grand work, by Daniel Ricciarelli, commonly called Da Votterra, at the altar of the church of Trinita da Monte, the subject of which is taking Christ down from the cross, is said to have been destroyed by the French, in their endeavours to remove it to France. Dorigny has engraved a large print of the design; and the picture has been thought so well worthy of attention, that an infinite multitude of copies have been made of it.

FRET, (from the Latin, *fretum,*) a species of guillochi, made of straight grooves or channelures at right angles to each other; the section of each channel being that of a rectangle. A fret is generally one connected groove with some of its parts in the same straight line. The labyrinth fret is that which consists of many turnings or windings, but in all cases the parts are parallel and perpendicular to each other. The prominent parts or interstices are generally of the same breadth throughout. In several Grecian examples, intervals are left in regular positions throughout the length of the fret.

FRET is also elaborate carved-work, the same as ENTAIL.

FRIARY, the building inhabited by a fraternity of friars.

FRIEZE, or FRIZE, (called by the Greeks *zoophorus*) the middle principal member of the entablature which separates the cornice from the architrave.

The frieze was supposed to be originally formed by the transverse beams, which were necessary to prevent the walls or sides from spreading outwards by the pressure of the rafters of the roof.

The Doric is the only order that has an enriched frieze peculiar to the order itself. The ornaments with which the friezes of the Ionic, Corinthian, and Roman orders are frequently decorated, are only accidental, and when introduced are accommodated to the circumstances or use of the building. When the frieze is charged with ornament, it ought to be higher than when plain. Vitruvius directs the frieze

of the Ionic to be one-fourth part less than the epistylium, when it is plain; and one-fourth part greater when ornamented; this seems reasonable, in order to set off the decorations to greater advantage.

Ancient examples show no authority for a general proportion in all the orders. In the Grecian Doric, the frieze is very high, being equal to the altitude of the architrave, and each of these greater than the cornice; the Corinthian, on account of the numerous members of the cornice, has its frieze less than one-third of the height of the entablature.

Vitruvius makes the line of separation between the frieze and the cornice immediately under the dentils, and not at the bottom of the cymatium, as by Palladio, Perault, and others; for the frieze must have a terminating member as well as the architrave.

Friezes are either *convex* or *pulvinated:* examples of the latter are to be met with as follow: at Rome, in the Composite order of the temple of Bacchus; Corinthian order of the basilica of Antoninus; and in the Composite order of the Goldsmiths' arch: in all which the curves are circular, and not very prominent. At Spalatro, in the Corinthian order of the portico of the vestibulum of the Periostilium; in the same order, exterior and interior, of the temple of Jupiter, and of the entrance of the temple of Æsculapius: where the curves are all circular, and very prominent. In Wood's *Ruins of Balbec* (as represented in plate 31) of the Corinthian order, where the curve is elliptical. In the Corinthian order of Wood's *Ruins of Palmyra,* (plates 23 and 46), the curve is elliptical; and in plates 33 and 40, it is circular. In the *Ionian Antiquities;* (vol. ii., plates 27 and 45) the curves are of a contrary flexure, with the concave part above; and in plate 50, the curve is circular.

Swelled friezes are to be found among the examples of antiquity, particularly during the decline of the Roman empire; but these precedents ought not to influence their use, as they are unnatural, and defeat the purpose they were intended to answer, namely, to form a relief to the eye between the cornice and the architrave.

Frieze, *Panel,* the upper panel of a six-panelled door.

Frieze, *Rail,* the top rail but one of a six-panelled door.

Friezes, *Flourished,* such as are enriched with reeds or imaginary foliages, as in the Corinthian frieze of the frontispiece of Nero.

Friezes, *Historical,* those which are adorned with bas-relievos, representing histories, or sacrifices, as those of the Parthenon and the temple of Theseus at Athens, and the arch of Titus at Rome.

Friezes, *Marine,* such as represent sea-horses, tritons, and other attributes of the sea; or shells, baths, grottos, &c.

Friezes, *Rustic,* those whose courses are rusticated, as the Tuscan frieze of Palladio.

Friezes, *Symbolical,* such as are adorned with the attributes of religion, as the Corinthian of the temple behind the Capitol at Rome, whereon are represented the instruments and apparatus of sacrifice.

Frieze of the Capital, the same as Hypotrachelion, which see.

FRIGERATORY, (from the Latin, *frigidus,* to cool) a place in a house intended to keep things cool in summer.

FRIGIDARIUM, (Latin) an apartment in which to keep things cool.

It also means the cold bathing-room in the baths of the ancients, as well as the vessel in which the cold water was received. The word has been likewise applied to the reservoir of cold water in the hypocaustum or stove-room, which was termed *ahenum frigidarium.*

FRIZE. *See* Frieze.

FRONT, (from the Latin, *frons,* the face,) any side or face of a building. The principal front should be that which commands the best prospect, or may be seen to the greatest advantage; and is generally the entrance-front.

FRONTAGE, the front part of an edifice.

FRONTAL, the hanging suspended over the front of the altar. It was made of the richest material, silk, velvet, and cloth of gold, and worked in the most costly manner in embroidery. Otherwise termed *Antependium.*

FRONTON, (French) a pediment, or other ornament over doors, niches, &c.

FROSTED, a species of rustic work, imitative of ice formed by irregular drops of water.

FROWEY TIMBER, such as works freely to the plane without tearing, and consequently has the grain nearly in the same direction.

FRUSTUM, (Latin) the part of a geometrical parallelogram next to the base, after cutting away the upper part, which contains the apex. Thus we have frustums of pyramids, cones, conoids, hemispheres, &c.

To measure the frustum of a square pyramid.

To the rectangle of the sides of the two bases, add one-third of the square of their difference; their product being multiplied by the height, will give the solidity.

Example.—In the frustum of a square pyramid, one side of the base A B or B C is 3 feet 6 inches, each side of the top 2 feet 3 inches, and the perpendicular height H I, 8 feet 9 inches, the solidity is required.

By Duodecimals.

	3 ··	6			
Deduct	2 ··	3			the less side of the top.
	1 ··	3			difference.
		1 ··	3		
		3 ··	9		
	1 ··	3			
3)	1 ··	6 ··	9		square of difference.
		6 ··	3		
	3 ··	6			
		2 ··	3		
	0 ··	10 ··	6		
	7 ··	0			
Add {	7 ··	10 ··	6		
		6 ··	3		one-third of the square of the difference.
	8 ··	4 ··	9		
			8 ··	9	
	6 ··	3 ··	7 ··	7	
	67 ··	2 ··	0		
	73 ··	5 ··	7 ··	7	the solidity required.

By Decimals.

3 ·· 6 = 3.5
2 ·· 3 = 2.25
8 ·· 9 = 8.75

```
       3.5
       2.25
       ----
       1.25 difference of the two bases.
       1.25
       ----
       625
      250
     125
     ------
  3) 1.5625 sq. of the difference of the two bases.
     ------
      .5208
     ------
       2.25
        3.5
     ------
       1125
       675
     ------
      7.875
Add   .5208 being 1/3 of the squ. of the difference.
     ------
     8.3958
       8.75
     ------
     419790
    587706
   671664
   --------
73.463250 the solidity required.
```

To measure the frustum of a cone.

To the rectangle of the two diameters, add one-third of the square of their difference: multiply the sum by .7854, and the product by the length.

EXAMPLE.—What is the solidity of the frustum of a cone, the diameter of the greater end being 3 feet, that of the lesser end being 2 feet, and the altitude 9 feet?

```
  3
  2
  -
  1 difference of the diameters.
  1
  -
  1 sq. of the difference of the diameters.
      3
      2
      -
      6
  Add 1/3
  -------
  Sum 6 1/3

   .7854
     6 1/3
  ------
   47124
    2618
  ------
  4.9742
       9 the length.
  ------
 44.7678 the solidity of the frustum.
```

FULCRUM, in mechanics, that by which a lever is sustained.

FUMARIUM, an upper room used by the Romans for collecting the smoke from the lower ones. The Fumarium was chiefly used, however, for smoking or ripening wines.

FUNNEL, that part of a chimney which is contained between the fire-place and the summit of the shaft. *See* CHIMNEY.

FURCATED, having a forked appearance.

FURLONG, a measure of length, the eighth part of a mile, forty poles.

FURNITURE, the fastenings of doors and windows with brass knobs, &c.

FURRING, when the edges of any number of timbers in a range are out of the surface they were intended to form, either from their gravity, or in consequence of an original deficiency of the timbers in their depth; the fixing of thin scantlings or laths upon the edges, so as to form that surface, is called *furring*. Thus the timbers of a floor, though level at first, are often obliged to be *furred:* in the reparation of old roofs, the rafters have mostly to undergo this operation: and the ceiling joists, both of new and old floors, frequently require it.

FURRINGS, the pieces of timber employed in bringing any piece of work in carpentry to a regular surface, when the work is deficient through the sagging of the timbers, or other causes.

FUR-UP. *See* FURRING.

FUST, (from the French) the shaft of a column, or trunk of a pilaster.

FUST, a term used in Devonshire, and perhaps in some other counties, for the ridge of a house.

FUSTIC, sometimes called YELLOW WOOD. This wood, the *Morus tinctoria*, is a native of the West Indies, and affords much colouring-matter, which is very permanent. The yellow given by fustic without any mordant, is dull and brownish, but stands well. The mordants employed with weld, act upon fustic in a similar manner, and by their means the colours are rendered more bright and fixed. The wood of this tree is also used in mosaic cabinet-work and turnery.

FUSUROLE, or FUSAROLE, (from the Latin) a semicircular member cut into beads, generally placed under the echinus of the Ionic and Roman capitals.

G.

GABION, a hollow cylinder of wicker-work, resembling a basket, but having no bottom. It is formed by planting slender stakes vertically in the ground, at intervals from each other, on the circumference of a circle, and interweaving with them osiers or other flexible twigs.

Such gabions are used during a siege, in executing trenches by the process of sapping: for this purpose, they are placed on end, with their sides inclining a little outwards, on that side of the line of approach which is nearest to the fortress; and, being filled with earth obtained by the excavation of the trench, they form a protection against the fire of the enemy. After the gabions are filled, the required thickness is given to the parapet of the trench by throwing the earth below the line.

GABLE, (from the British, *gravel*) the upper portion of the end of a building wall, which closes the end of the roof, in shape similar to a triangle, and answering, in some respects, to the term PEDIMENT, applied to classic architecture. The gable forms a prominent feature in mediæval buildings, and its shape conforms to that of the roof; which is various at different periods. In Norman buildings, the angle of the roof is as nearly as possible a right angle, while in Early English edifices the gable is frequently an equilateral triangle. In the Decorated the roof is somewhat depressed, which depression increases in the Perpendicular and later buildings. The finish to Norman gables was probably a flat coping, to Early English a moulded coping, sometimes further ornamented with crockets and finials; but these were more frequently introduced in the later styles, in which also the gables were sometimes finished with a pierced parapet or battlement. In Domestic architecture, gables with overhanging roofs were ornamented with BARGE-BOARDS.

The term is also applied to the entire wall at the gable-end of a building.

GABLE-ROOFED, having a roof abutting against a gable wall.

GABLE-WINDOW, a window in the gable end of a building.

GABLET, a small gable; an ornament in shape like a gable, frequently introduced over tabernacles, niches, buttresses, &c.

GAGE, (French) in carpentry and joinery, an instrument for drawing one or more lines on any side of a piece of stuff, parallel to one of the arrises of that side.

There are four kinds of gages: the common gage, the mortise-and-tenon gage, the internal gage, and the flooring gage. The common gage and the flooring gage are both applied to the drawing of a line parallel to an arris.

The common gage consists of two pieces of wood, one of which passes through a mortise in the other, and has an iron or steel tooth fixed near one of its extremities; so that the point may be placed at any distance from the mortised piece: then the piece which passes through the mortise is fixed by a wedge also through that piece: the piece through which the mortise passes is called *the head*, and the piece passing through the mortise, in which the iron tooth is fixed, is called *the staff.*

When a line is drawn from the arris upon one side, at a given distance, the head is a fence that always keeps the staff at right angles to the arris, and equidistant, in moving it to and fro.

The mortise-and-tenon gage is a common gage with a longitudinal slider, moveable in a dovetail groove: the slider has also a tooth fixed as near to the end next the tooth in the end of the staff as possible; so that the teeth may be brought almost to any distance from one another.

The internal gage is constructed similar to the staff of the mortise-and-tenon gage: it has a longitudinal slider, the whole length of the staff, without a head, or any other tooth than that of the slider.

The flooring gage consists of a head and staff fixed together, at a very obtuse angle: on the head are a number of equidistant furrows at right angles to the staff: the section of each furrow is an internal right angle, one side of which is in a straight line with the tooth, and the other becomes a fence in the act of gaging.

This gage is made to answer battens or deals of various widths: Each width is numbered, according to the furrow that is applied as a fence; so that a flooring board, which is not sufficiently long, may be extended, by a piece of the same breadth, to the length required.

GAIN, the bevelled shoulder of a binding-joist for the purpose of giving additional resistance to the tenon below. *See* TUSK.

GALILEE, a porch, usually built at or near the west end of the great abbey-churches, where the monks collected themselves, and drew up in returning from some of their processions; where dead bodies were deposited previous to their interment; and where, in certain monasteries, females alone were allowed to see the monks to whom they were related, or to attend divine service.

Galilees exist in England in the cathedrals of Durham, Ely, and Lincoln. In the former instance, it is a large chapel at the west end of the nave, measuring 80 feet by 50, and divided into five aisles by semi-circular arcades on clustered columns; it likewise contained three altars. The galilee at Ely is in the same position, but of much smaller dimensions, while that at Lincoln is on the west side of the south transept.

Many improbable conjectures have been formed concerning the derivation of the name. The real occasion of it seems to be this: when any female applied at the abbey-gate for leave to see her relative, who was a monk, she was directed to the western porch of the church, and told, in the terms which so frequently occur in the service of the pascal time, alluding to Matt. xxviii. 10, and Mark xvi. 7, that she should see him in Galilee. This explanation is confirmed by a passage of Gervasius the monk of Canterbury. *De Combust. et Repar. Dorob. Ecc. Twysd. X. Script.*

GALLERY, an apartment of a house, not always destined to answer the same purpose: the term is applied, in a general way, to any passage or apartment, the length of which greatly exceeds its breadth. A common passage to several rooms in one range, in any upper story of a house, is called a gallery; a long room for the reception of pictures is called a gallery; the platform raised upon pillars, or projected from the wall of a church, open in the front to the central space, for the accommodation of a greater number of people than the body of the church would admit, is called a gallery. The whispering-gallery of St. Paul's, as also that of the chapel of Green-

wich Hospital, are projected, and supported by cantalivers from the wall. The whole, or a portion of the uppermost story of a theatre, is likewise called a gallery. The appellation is also frequently given to porticos formed with long ranges of columns on one side.

Savot, in his *Architecture*, derives the gallery from *Gaul*, as supposing the ancient Gauls to have been the first who used them: Nicod, from the French, *aller*, to go; q. d. *allerie:* others bring it from *galère*, galley, because it bears some resemblance thereto in respect of health.

The length of galleries is (according to Palladio) from eight to ten times their breadth.

GANG-LADDER, in canal-making, a frame answering the same purpose as a horsing block.

GANG-WAY, a temporary stair, made with planks set edge to edge of each other, having transverse pieces of wood nailed over for steps; used particularly by masons, bricklayers, and carpenters, for ascending or descending the various stories of a building, before the stairs are put up.

GAOL, (from the French, *géole*, formed of the Latin, *geola*, *gaola*, or *gayola*, a cage) a prison, or place of legal confinement; the word is now generally written JAIL.

Every county has two gaols; one for debtors, which may be any house where the sheriff pleases; the other for the peace and matters of the crown, which is the county gaol.

By 22 and 23 Car. II. c. 20, the gaoler shall keep debtors and felons separate, on pain of forfeiting his office, and treble damages to the party aggrieved; and by 31 Geo. III. c. 46, transports are to be kept separate from other prisoners. As the gaol is intended, in most cases, for custody, and not for punishment, it is enacted by 14 Geo. III. c. 59, that the justices, in their several quarter-sessions, shall order the walls and ceilings of the several cells and wards, both of the debtors and felons, and of any other rooms used by the prisoners in their respective gaols, where felons are usually confined, to be scraped and whitewashed once in the year, at least, and to be regularly washed and kept clean, and constantly supplied with fresh air by hand-ventilators or otherwise; and shall order two rooms in each gaol, one for the men and another for the women, to be set apart for sick prisoners; and order a warm and cold bath, or commodious bathing-tub, to be provided in each gaol, and direct the prisoners to be washed in such warm or cold baths, or bathing-tubs, &c., and they shall appoint an experienced surgeon and apothecary, at a stated salary, to attend the gaol, and to report, at each quarter-sessions, the state of the health of the prisoners; order clothes for the prisoners when they see occasion, prevent their being kept under ground, when it can be done conveniently, and from time to time make orders for restoring or preserving the health of the prisoners; the expenses to be paid out of the county rates, or out of the public stock of any city, franchise, or place to which the gaols belong. The gaoler is subject to fine for neglect or disobedience of the orders of justices, by complaint to the judges of assize, or to the justices in their quarter-sessions. By 31 Geo. III. c. 46, visiting-justices are appointed for inspecting gaols at least three times in each quarter of a year, in order to prevent abuses, &c., and they are to report to the quarter-sessions. The justices in sessions may also appoint clergymen to officiate in gaols, and allow them a salary to be paid out of the county rates.

If a gaol be out of repair, insufficient, &c., the justices of the peace in their quarter-sessions may agree with workmen for rebuilding or repairing it; and by warrant under their hands and seals, order the sum agreed upon to be levied upon the several hundreds and divisions in the county, by a proportionate rate; and the justices in sessions may borrow, on mortgage of the said rates, any sum not less than £50 nor more than £100, and discharge the whole by yearly payments. 11 and 12 Will. III. cap. 19. 24 Geo. III. c. 54. *See* PRISON.

GARD, *Pont du*. *See* AQUEDUCT, BRIDGE.

GARDEN, *Hanging*, a sort of ancient garden, which is said to have been formed in a raised manner, on arches, by Nebuchadnezzar king of Babylon, with the view of gratifying his wife Amyctis, who was the daughter of Astyages, king of Media. These gardens are supposed by Quintus Curtius to have been equal in height to the city, which is 50 feet. They contained on every side a square of 400 feet, and were carried up in several terraces, surmounting each other, to which there were ascents by different flights of stairs or steps that had 10 feet in width. The arches that sustained the whole of this pile were raised above each other, being strengthened by a wall on every side of above seven yards in thickness. The floors of the several terraces were laid first with large flat stones, of considerable lengths and breadths, over which was placed a stratum of reed mixed very fully with bitumen, then two rows of bricks closely cemented together with mortar, and the whole afterwards covered with thick sheet-lead, upon which the mould of the garden was deposited, to such a depth as to admit large trees to take root and establish themselves in it. Trees, plants, and flowers of various kinds, were introduced into these gardens. The upper terrace was likewise provided with an aqueduct or engine, by which the water was drawn up from the river, and dispersed over the whole of the gardens when necessary.

Some have condemned these gardens as unnatural, while others have considered them as deserving of a portion of praise; but whatever merit may have been allowed them, they could certainly never have had anything of the natural or rural character about them.

GARDEN-SHEDS, erections for containing garden implements, flower-pots, hot-bed frames, and glass sashes; also for working in, during bad weather. They are best placed on the back-wall of the tool-house, by which means they may be made to hold the furnaces, fuel, and other articles.

GARGOYLE, GARGLE, GARGYLE, AND GURGOYLE, a stone projecting from the wall of Gothic buildings, and serving for a spout to convey the water from the roof, and throw it off the wall. These stones are more frequently carved into grotesque figures or animals, through the mouth of which the water passes; sometimes, however, the water is carried through a leaden pipe above or below the figure. Their usual position is in the cornice of buildings, but they are found also in other positions, such as buttresses, &c.

GARLANDS, (from the French, *guirlande;* from the Latin, *garlanda*, or Italian, *ghirlanda*,) ornaments of flowers, fruits, and leaves, anciently used at the gates of temples, where feasts or solemn rejoicings were held. Garlands of festoons were also put on the heads of victims, in the ancient heathen sacrifices.

GARNETS, *Cross*, a species of hinge, used in the most common works, formed in the shape of the letter T, turned thus, ⊢, the vertical part being fastened to the style or jamb of the door-case, and the horizontal part to the door or shutter.

GARRET, (from the French, *garite*, the tower of a citadel) the uppermost story of a house, when taken either partially or wholly from the space within the roof.

GARRETING, the insertion of small pieces of stone between the joints of rough masonry, as in rubble and flint walls.

GARRISON, a fort, castle, or fortified town, furnished with troops to defend it.

GATE, a large door for shutting the entrance of parks, fields, towns, castles, palaces, or any other considerable buildings.

The width of gates is from eight to twelve feet: the height depends upon the purpose to which they are applied. *See* Door.

Gate, in *Rural Economy*, a frame of wood constructed with a number of bars, and fixed in such a manner as to swing upon hinges, for the purpose of affording convenient passage into and out of inclosed grounds, or other places.

In the constructing of gates, of whatever kind or form they may be, the materials should constantly be well prepared by proper seasoning before they are put together; as, where this is not the case, they soon become much injured by their constant exposure to the effects of the sun and wind. They also require that the different parts be put together with considerable accuracy and correctness. In respect to durability, there can be no doubt but that oak is by much the best sort of wood to be employed; but some of the more light kinds of wood, such as those of the deal, willow, and alder sorts, answer the purpose extremely well, and are very durable, as, on account of their lightness, they do not destroy themselves so much in shutting. It is found by experience that the lighter gates can be made in their foreparts, so that they be sufficiently strong for the intended purpose, the better they answer. For this reason, in some cases, as where horses are chiefly to be confined, the top bars, by being left of more strength, may admit of the others having less substance; but if this be not done, they are apt to be broken by the horses rubbing their necks upon them, unless where they are made of great height.

The width of gates for general purposes is mostly from eight and a half to nine feet, and the height from five to six feet; the bars being five or six in number, and each four or five inches in breadth. Hence they are frequently denominated five or six-barred gates. In cases where fowls or other small animals are to be guarded against, it is better to run a smaller bar between the two lowermost ones, as by this means their passage is prevented.

Gate, in *Engineering*, is applied to the close-boarded doors of locks or sluices on canals or rivers, for penning up the water: in a lock these are distinguished by upper-gates and lower-gates, according as they are placed at the head or tail of the lock.

Gate-House, a building erected over a gate, or that through which entrance was obtained into the main building. Gate-houses were very usual in the erections of the middle ages, and were employed in all large buildings, ecclesiastical, military, and civil, also as entrances to fortified cities; thus in London we still preserve the names of several gate-ways in the old wall, as New-gate, Bishops-gate, Lyd-gate, &c., at each of which places was formerly a gate-house, through which entrance was obtained within the city. These buildings were often of an imposing character; and in military works consisted, for the most part, of a large arch-way with groined ceiling, and a portcullis at each end, flanked by two massive projecting towers, pierced with loop-holes, through which to annoy the enemy, and surmounted by a battlemented parapet. Those attached to civil and ecclesiastical buildings were generally of a more ornamental description, sometimes consisting of only a square tower with a turret at one or more angles, having a large arch-way in the centre with groined ceiling and room above, the window of which—frequently an oriel—formed a picturesque addition to the elevation. The forms of these gate-houses were, however, various, and admitted of different degrees of ornamentation. In some cases, there was a small arch-way by the side of the principal one for foot-passengers, and in others a similar one on either side; they were called posterns. Remains still exist in most of the old towns, amongst the most remarkable of which are those of Battle Abbey, Sussex, Bristol, Bury St. Edmund's, St. John's Gate, Clerkenwell, and St. Augustine's College, Canterbury.

Gate-way, the passage through which entrance is obtained into a town, building, &c.

GATHERING OF THE WINGS, in a chimney, the sloping part above the fire-place, where the funnel contracts or tapers till it reaches the tube or flue.

GAVEL, the same as Gable, which see.

GAUGE, *See* Gage.

Gauge, a term applied to signify the width between the rails on a railway.

GEMMEL, Gymmer, or Chymol, an ancient term for a hinge.

GENERATING LINE, or Plane, in geometry, is a line, or plane, moving according to a given law, either round one of its extremities, as a fixed point or axis, or parallel to itself, in order to generate a plane figure or solid, which is formed by the space it has gone over.

GENESIS, (from the Greek, γένεσις, *origin*, or *beginning*) in geometry, the formation of a line, plane, or solid, by the motion of a line, plane, or surface; thus, a sphere is conceived to be generated by the motion of a semicircle revolving on its diameter, which is called *the axis of circumvolution*. A triangle may be conceived to be generated by the motion of a line parallel to its base, in such a manner that the describing line must be a fourth proportional to the base, the altitude, and the distance of the line from the vertex of the triangle.

In the genesis of figures, the moving point, line, or surface, is called *the describent*, and the line round which, or according to which, the revolution is made, *the dirigent*.

GENTESE, in Early English architecture, cusps or featherings in the arch of a doorway.

GEOD'ESY, that branch of applied mathematics which determines the figures and areas of large portions of the earth's surface, the general figure of the earth, and the variations of the intensity of gravity in different regions by means of direct observation and measurement.

GEOLOGY, the science which treats of the internal structure of the earth as far as we have been able to penetrate below its surface, of the arrangement of the materials of which it is composed, and of the changes which have taken place in them.

GEOMETRICAL, something that has a relation to geometry: thus we say, geometrical method, geometrical genius, geometrical strictness, geometrical construction, geometrical demonstration, &c.

Geometrical Locus, or Place. *See* Locus.

Geometrical Pace, a measure of five feet.

Geometrical Plan. *See* Plan.

Geometrical Plane, in perspective, the same as *ground plane*, or *original plane*.

Geometrical Solution of a Problem, a solution according to the strict principles of geometry, by lines that are truly geometrical.

In this sense, we say, *a geometrical solution*, in contradistinction to *a mechanical* or *an instrumental solution*, where the problem is only solved by ruler and compasses.

Geometrical problems are distinguished into three kinds, viz., plane, solid, and linear.

Plane problems are such as may be solved by a right line and a circle.

Solid problems are derived from the consideration of a solid that is a cone.

Linear problems are derived from lines more compounded.

Geometrical Stair, such as is only supported by the wall at the one end of the steps, with a continued string at the other.

GEOMETRY, (from the Greek, γεωμετρια, formed of γεα or γη, *earth*, and μετρεω, *to measure*) the doctrine, or science of extension, or things extended, viz. of lines, surfaces, or solids. Geometry has also been defined in general terms as the science of space.

According to Herodotus, Strabo, and Diodorus, the Egyptians were the first inventors of geometry, and it is asserted by these ancient writers, that to the annual inundations of the Nile, we are to attribute the first steps in this science. That river, in its overflowings, bearing away all the bounds and landmarks of men's estates, and covering the whole face of the country, the people were obliged to distinguish their lands by the consideration of their figure and quantity; and thus, by experience and habit, they formed to themselves a method, or art, which was the origin of geometry. A farther contemplation of the draughts of figures of fields thus laid down, and plotted in proportion, might, naturally enough, lead them to the discovery of some of their excellent and wonderful properties; and as these speculations continually improved, so the art gradually improved also, until it attained the perfection of the present day. Josephus, however, seems to attribute the invention to the Hebrews; and others, among the ancients, make Mercury the inventor.

From Egypt, geometry passed into Greece, being carried thither, as some say, by Thales, where it was much cultivated and improved by himself, Pythagoras, Anaxagoras of Clazomene, Hippocrates of Chios, and Plato. The latter testified his conviction of the necessity and importance of geometry, in order to the successful study of philosophy, by the following inscription on the door of his academy: "*Let no one ignorant of geometry enter here.*" Plato, conceiving that geometry was too mean and restricted an appellation for this science, substituted for it the more extensive name of *mensuration;* and others have denominated it *pantometry.* Other more general and comprehensive appellations are perhaps more suitable to its extent, especially in the present advanced state of the science; and accordingly, some have defined it as *the science of inquiring, inventing, and demonstrating all the affections of the magnitude.* Proclus calls it *the knowledge of magnitudes and figures, with their limitations;* as also of their ratios, affections, positions, and motions of every kind. About fifty years after Plato, lived Euclid, who collected together all those theorems which had been invented by his predecessors in Egypt and Greece, and digested them into fifteen books, intitled the *Elements of Geometry;* and those propositions which were not satisfactorily proved, he more accurately demonstrated. The next to Euclid, of those ancient writers whose works are extant, is Apollonius Pergæus, who flourished in the time of Ptolemy Euergetes, about two hundred and thirty years before Christ, and about one hundred years after Euclid. The third ancient geometer, whose writings remain, is Archimedes of Syracuse, who was famous about the same time with Apollonius. We can only mention Eudoxus of Cuidus, Architas of Tarentum, Philolaus, Eratosthenes, Aristarchus of Samos, Dinostratus, the inventor of the quadratrix, Menechmus, his brother, and the disciple of Plato, the two Aristeuses, Conon, Thrasideus, Nicoteles, Leon, Theudius, Hermotimus, and Nicomedes, the inventor of the conchoid; besides whom there are many other ancient geometers, to whom this science is indebted.

The Greeks continued their attention to geometry, even after they were subdued by the Romans. Whereas the Romans themselves were so little acquainted with this science, even in the most flourishing time of their republic, that they gave the name of mathematicians, as Tacitus informs us, to those who pursued the chimeras of divination and judicial astrology. Nor were they more disposed to cultivate geometry, as we may reasonably imagine, during the decline, and after the fall of the Roman empire. The case was different with the Greeks; among whom we find many excellent geometers, since the commencement of the Christian era, and after the translation of the Roman empire. Ptolemy lived under Marcus Aurelius; and we have, extant, the works of Pappus of Alexandria, who lived in the time of Theodosius; the commentary of Eutocius, the Ascalonite, who lived about the year of Christ 540, on Archimedes' mensuration of a circle; and the commentary on Euclid, by Proclus, who lived under the empire of Anastasius.

The consequent inundation of ignorance and barbarism was unfavourable to geometry, as well as to the other sciences; and those few who applied themselves to this science, or indeed to any branch of learning incomprehensible by the vulgar, were calumniated as magicians. In those times of European darkness, the Arabians were distinguished as the guardians and promoters of science; and from the ninth to the fourteenth century they produced many astronomers, geometers, geographers, &c., from whom the mathematical sciences were again received into Spain, Italy, and other parts of Europe, somewhat before the beginning of the fifteenth century. Some of the earliest writers after this period, are Leonardus Pisenus, Lucas Paciolus or de Burgo, and others who flourished between 1400 and 1500. After this period appeared many editions of Euclid, or commentaries upon his *Elements; e.g.*, Orontius Fineus, in 1530, published a commentary on the six first books; as did James Peletarius in 1557; and about the same time, Nicolas Tartaglia published a commentary on the whole fifteen books. We might also mention other editions or commentaries; such as those of Commandine, Clavius, Billingsly, Scheubelius, Harlinus, Dasypodius, Ramus, Herigon, Stevinus, Saville, Barrow, Tucquet, Dechales, Furnier, Scarborough, Keill, Cann, Stone, and many others.

At the revival of letters, there were few Europeans capable of translating and commenting on the works of the ancient geometers; and geometry made consequently but little progress till the time of Des Cartes, who published his *Geometry* in 1637. However, not to mention all those who extended geometry beyond its elementary parts, such as Theodosius, in his *Spherics*, Serenus, in his *Sections of the Cone and Cylinder;* Kepler, in his *Nova Stereometria*, &c.; in 1635, Bonaventure Cavalerius, an Italian, of the order of Jesuits, published his *Geometry of Indivisibles;* Torricelli, his *Opera Geometrica;* Viviani, his *Divinationes Geometricæ, Exercitatio Mathematica, De Locis Solidis, De Maximis et Minimis*, &c.; Vieta, *Effectio Geometrica*, &c.; Gregory St. Vincent, in 1647, published his treatise, intitled *Quadratura Circuli et Hyperbolæ*, a work abounding with excellent theorems and paralogisms; and Pascal, about the same time, published his *Treatise of the Cycloid.* Geometry, as far as it was capable of deriving aid and improvement from the arithmetic of infinites, was indebted to the labours of Fermat, Barrow, Wallis, Mercator, Brounker, J. Gregory, Huygens, and others; to whom we may add Newton and Leibnitz. But Sir Isaac Newton contributed to the progress of pure geometry by his two treatises, *De Quadratura Curvarum*, and *Enumerätio Linearum Tertii Ordinis:* and still farther by his incomparable and immortal work, intitled, *Philosophia Naturalis Principia Mathematica*, which will always be considered as the most extensive and successful application of geometry to physics.

The modern Geometers are innumerable; and the names of Cotes, Maclaurin, R. Simpson, T. Stewart, T. Simpson, &c. not to mention living writers, will always be held in esteem and veneration by those who are devoted to the study of geometry and mathematics.

The province of geometry is almost infinite: few of our ideas but what may be represented to the imagination by lines, upon which they become of geometrical consideration: it being geometry alone that makes comparisons and finds the relations of lines.

Architecture, mechanics, astronomy, music, and in a word, all the sciences which consider things susceptible of more and less, *i. e.* all the precise and accurate sciences, may be referred to geometry; for all speculative truths consisting only in the relations of things, and in the relations between those relations, they may be all referred to lines. Consequences may be drawn from them; and these consequences, again, being rendered sensible by lines, become permanent objects, which may be constantly exposed to a rigorous attention and examination: thus affording to us infinite opportunities both of inquiring into their certainty, and pursuing them farther.

Geometrical lines and figures are not only proper to represent to the imagination the relations between magnitudes, or between things susceptible of more and less; as spaces, times, weights, motions, &c., but they may even represent things which the mind can no otherwise conceive, for example, the relations of incommensurable magnitudes.

It must be observed, that this use of geometry among the ancients was not strictly scientifical, as among us; but rather symbolical: they did not argue, or deduce things and properties unknown, from lines, but represented or delineated by them things that *were* known. In effect, they were not used as means or instruments of discovering, but as images or characters, to preserve, or communicate, the discoveries already made.

The ancient geometry was confined to very narrow bounds, compared with the modern. It only extended to right lines and curves of the first order, or conic sections; whereas in modern geometry new lines, of infinitely more and higher orders, are introduced.

Geometry is commonly divided into four parts, or branches; Altimetry, Stereometry, Planimetry, and Longimetry. See those words.

It is again distinguished into *theoretical* or *speculative*, and *practical.* The first contemplates the properties of continuity; and demonstrates the truth of general propositions, called *theorems.* The second applies those speculations and theorems to particular uses in the solution of *problems.* Speculative geometry, again, may be distinguished into *elementary* and *sublime.* The former is that employed in the consideration of right lines and plane surfaces, and solids generated from them. The *higher* or *sublime* geometry is that employed in the consideration of curve lines, conic sections, and bodies formed of them.

The science of geometry is founded on certain axioms, or self-evident truths; it is introduced by definitions of the various objects which it contemplates, and the properties of which it investigates and demonstrates, such as points, lines, angles, figures, surfaces and solids:—lines again are considered as straight or curved; and in their relation to one another, either as inclined or parallel, or as perpendicular:—angles, as right, oblique, acute, obtuse, external, vertical, &c.:—figures, with regard to their various boundaries, as triangles, which are in respect to their sides equilateral, isosceles, and scalene, and in reference to their angles, right-angled, obtuse-angled, and acute-angled; as quadrilaterals, which comprehend the parallelogram, including the rectangle and square, the rhombus and rhomboid, and the trapezium and trapezoid; as multilaterals or polygons, comprehending the pentagon, hexagon, heptagon, &c.; and as circles;—also as solids, including a prism, parallelopipedon, cube, pyramid, cylinder, cone, sphere, and the frustum of either of the latter.

For practical geometry, the fullest and most complete treatises are those of Mallet, written in French, but without the demonstrations; and of Schwenter and Cantzlerus, both in high Dutch. In this class are likewise to be ranked Clavius's, Tacquet's, and Ozanam's *Practical Geometries;* De la Hire's *Ecole des Arpenteurs;* Reinholdus's *Geodæsia;* Hartman Beyers's *Stereometria;* Voigtel's *Geometria Subterranea;* all in high Dutch: Hulsius, Galileus, Goldmannus, Scheffelt, and Ozanam, *on the Sector*, &c. &c. An excellent treatise on practical geometry, particularly with reference to the study of architecture and perspective, was published some years ago by Mr. Peter Nicholson, and still holds its ground in public estimation, notwithstanding the numerous works on the subject which have appeared from time to time. The following short essay on Practical Geometry, containing the formation of plain figures arising from straight lines and circles, will also be found exceedingly useful in the study of architectural construction. Curves of variable curvature, as those arising from the sections of a cone by a plane, will be found under their respective heads; as, Conic Sections, Ellipsis, &c.

Geometry, *Analytical*, or *Descriptive*, the method of finding the situation of a point in a plane. *See* Descriptive Geometry.

Geometry, *Practical*, the method of reducing or applying the rules of the science to practice, examples of which will be found in the following problems.

Problem I.—*In a right line,* A B, *from any given point,* C *to erect a perpendicular.*

Figure 1.—When the given point is near the middle of the line. On each side of the point C, on the line A B, take any two equal distances, as C *d*, C *e;* from *d* and *e*, with any radius greater than C *d*, or C *e*, describe arcs of equal radii, cutting each other in F; through the points F and C, draw the right line F C, and it will be the perpendicular required.

Figure 2.—When the given point is at or near the end of the line. Take any other point, as *d*, in A B; from *d*, with the distance *d* C, describe an arc, C *e f;* take the portion C *e*, of the arc, at pleasure, and make the portion *e f* equal to C *e;* draw the chord C *g f;* from C, with the radius C *e*, describe the arc *g e* H; make *e* H equal to *e g;* and through the points C and H draw the right line C H, which is the perpendicular required.

Figure 3.—Another method. Take any other point, *d*, as before: from C, with the distance C *d*, describe an arc, *d e f;* from *d*, with the same radius, describe an arc at *e;* from *e*, with the same radius, describe an arc at G; draw *d e* G, and through the points G and C draw G C, which is the perpendicular required.

Problem II.—*From a given point,* C, *to drop a perpendicular upon a given right line,* A B.

Figure 4.—In A B, take any two points, *f* and *g;* and from either point, *f*, with the radius *f* C, describe an arc, C E; from *g*, with the distance *g* C, describe arcs at C and E, of equal radii; and draw the right line C E, which is the perpendicular required.

Figure 5.—Another method. From the point C, describe an arc, *f g*, cutting A B at *f* and *g;* from the points *f* and *g*, with any equal radii greater than the half of *f g*, describe two arcs, cutting each other in D; draw C D, and C D is perpendicular to A B, and drawn from the point C, as required.

Problem III.—*To draw a right line parallel to a given right line*, A B, *at a given distance*, C D.

Figure 6.—Take any points, as *e* and *f*, in the right line A B; then, with the distance C D, from the points *e* and *f*, describe arcs, G and H, of equal radii; draw the right line G H to touch the arcs at G and H; and G H will be parallel to A B, at the distance C D, as required.

Problem IV.—*Through a given point*, C, *to draw a right line parallel to a given right line*, A B.

Figure 7.—In A B, take any two points, as *d* and *e*, and draw C *d*; make the angle B *e* F equal to the angle B *d* C; make *e* F equal to *d* C; and draw the right line C F, which passes through the point C, and is parallel to A B, as required.

Figure 8.—Another method. Take any point, as *e*, in A B, and from *e*, with the distance *e* C, describe an arc, C *d*, cutting A B in *d*; from C, with the same distance, C *e*, describe an arc, *e* F; make *e* F equal to *d* C; draw the right line C F, and it will pass through C, parallel to A B, as required.

Problem V.—*To bisect a right line*, A B, *by a perpendicular.*

Figure 9.—Take any distance greater than the half of A B; from the points A and B, describe arcs of equal radii, cutting each other at C and D; draw C D, and it will be perpendicular to A B, and bisect A B at the point E, as required.

Problem VI.—*At a given point*, E, *in a right line*, E F, *to make an angle equal to a given angle*, A B C.

Figures 10 *and* 11.—From B, with any radius, describe an arc, as *g h*, cutting B C at *g*, and B A at *h*; from E, with the same radius, describe another arc, *i k*, meeting E F at *i*; make *i k* equal to *g h*; draw the right line E *k* D; and the angle D E F is equal to the angle A B C, as required.

Problem VII.—*To bisect a given angle*, A B C.

Figure 12.—From A B, cut off any part, as B *d*; take the part B *e* from B C, equal to B *d*; from the points *d* and *e*, with any distance greater than the half of *d e*, describe arcs of equal radii, cutting each other at F; draw F B, and it will bisect the angle A B C, as required.

Problem VIII.—*To bisect a given arc*, A B C, *of a circle.*

Figure 13.—Draw the chord A C; bisect A C by a perpendicular, B D; and the point B will divide the arc A B C into two equal arcs, A B, B C.

Problem IX.—*A circle*, A B C A, *and a tangent*, D E, *to the circumference, being given to find the point of contact.*

Figure 14.—Let the centre, F, be given; draw F A perpendicular to D E; and the point, A, where it cuts the tangent, is the point required.

Figure 15.—If the centre be not given, draw the chord F G, parallel to the tangent D E; bisect F G by a perpendicular, H A, meeting the tangent at A; then A is the point of contact required.

Problem X.—*An arc*, A B C, *and a point* B, *in the circumference being given; to draw a tangent through the point*, B.

Figure 16.—From the point B, cut off two equal arcs, B D, and B E; draw the chord D E; through B, draw F G, parallel to D E; and F G is the tangent sought.

Problem XI.—*Given a circle*, A B C, *and a straight line*, D E, *equal to, or less than the diameter; from a given point*, A, *in the circle, to inscribe a chord equal to* D E.

Figure 17.—From the point A, with a radius equal to D E, describe an arc, cutting the circumference at B; draw A B, which is the chord required.

Problem XII.—*In a given circle*, A B C D, *to inscribe an equilateral triangle; or to divide the circle into three equal parts.*

Figure 18.—With the radius of the circle cut off the arcs A D, D B; join A B; from A, with the radius A B, describe an arc, cutting the circumference at C; join A C, C B; and A B C is the equilateral triangle required.

Problem XIII.—*In a given circle*, A B C D A, *to inscribe a square; or to divide the circumference into four equal parts.*

Figure 19.—Through the centre, E, and any point, A, in the circumference, draw the diameter A C; and the diameter B E D, perpendicular to A E C; draw the chords A B, B C, C D, D A; and A B C D A will be the square required.

Problem XIV.—*In a given circle*, A B C D E A, *to inscribe a pentagon; or to divide the circumference into five equal parts.*

Figure 20.—Draw the diameters A *i f* and *g i h* at right angles to each other; bisect the radius *g i* at *k*; from *k*, with the distance *k* A, describe an arc A *l*, cutting *g h* at *l*; and from A, with the distance A *l*, describe an arc cutting the circle at B; draw the chord A B; make the successive chords, A B, B C, C D, D E, each equal to A B; join E A, and A B C D E A will be the pentagon required.

Problem XV.—*In a given circle*, A B C D E F A, *to inscribe a hexagon; or to divide the circle into six equal parts.*

Figure 21.—From any point, as A, draw the successive chords A B, B C, C D, D E, E F, each equal to the radius, and join the last, F A; then A B C D E F A will be the hexagon required; or the circle will be divided into six equal parts.

Corollary.—Hence, by the first of the three last problems, the circle may be divided into eight equal parts; by the second, it may be divided into ten equal parts; and by the third, it may be divided into twelve equal parts, only by bisecting the arcs: and if each arc be again bisected, each circle will be divided into four times the number of equal parts, as at first. The above are the only truly geometrical methods of dividing circles into equal parts, no general method having been discovered.

Problem XVI.—*Upon a given straight line*, A B, *to describe an equilateral triangle.*

Figure 22.—From the points A and B, with the distance A B, describe arcs, cutting each other in C; draw C A and C B; and A B C is the equilateral triangle required.

Problem XVII.—*Upon a given straight line*, A B, *required to describe a square, or tetragon.*

Figure 23.—Bisect A B by a perpendicular *e i*; make *e i* equal to the half of A B; from *i*, with the distance *i* A or *i* B, describe a circle; draw the chords B C, C D, equal to A B; join D A; and A B C D is the square or tetragon required.

Problem XVIII.—*Upon a given straight line*, A B, *to describe a regular pentagon.*

Figure 24.—Draw B *f* perpendicular and equal to the half of A B; produce A *f* to *g*, making *f g* equal to *f* B; from the points A and B, with the radius B *g*, describe arcs, cutting each other at *i*; from *i*, with the radius *i* A, or *i* B, describe a circle; inscribe the successive chords B C, C D, D E, each equal to A B; join E A; and A B C D E A is the pentagon required.

Problem XIX.—*Upon a given straight line*, A B, *to describe a regular hexagon.*

Figure 25.—From the points A and B, with the distance A B, describe arcs, cutting each other at *i*; from *i*, with the distance C A, or C B, describe a circle, A B C D E F A; make the successive chords B C, C D, D E, E F, each equal to A B, and join F A; and A B C D E F is the hexagon required.

Problem XX.—*Upon a given straight line*, A B, *to describe an octagon, a decagon, or a dodecagon.*

Figures 26, 27, *and* 28.—Find the centre, *i*, of a circle, by such of the three last Problems as will contain a polygon of half the number of sides required; draw *i k* upwards, perpendicular to A B, equal to *i* A or *i* B; and the point *k* will

be the centre of a circle that will contain the polygon required.

Example I. *Figure* 26.—For an octagon, find the centre, *i*, as in Problem XIII.

Example II. *Figure* 27.—For a decagon, find the centre, *i*, as in Problem XIV.

Example III. *Figure* 28.—For a dodecagon, find the centre, *i*, as in Problem XV.

Complete the remaining parts as above directed; and thus a circle may be found to contain any duplical multiple of these sides.

Problem XXI.—*Through three given points,* A, B, C, *to describe the circumference of a circle, provided the three points be not in the same straight line.*

Figure 29.—Join A B and B C, and bisect them by perpendiculars meeting each other at D; from D, with the distance A D, of either point, describe a circle, and its circumference will pass through the other two points B and C.

Problem XXII.—*To describe a circle of a given radius through two given points,* A *and* B, *provided the radius be greater than half the distance between the two given points.*

Figure 30.—From A, with the given radius, describe an arc from B; with the same radius, describe another arc, cutting the former at C; from C, with the distance C A, or C B, describe the circle A B D; and it will be the circle required.

Problem XXIII.—*To describe a circle to pass through two given points,* A *and* B, *and touch a straight line,* C D; *provided the two points and the straight line be not in the same straight line.*

Figure 31.—Produce A B and D C, to meet in E; bisect the angle A E D by the straight line E F; bisect A G by the perpendicular G F; from the point of concourse, F, with the radius F G, describe a circle, G H I K, which is the circle required.

Problem XXIV.—*To describe a circle to pass through a given point,* A, *and touch two straight lines,* B C *and* D E, *provided that the point be situated between the two lines.*

Figure 32.—Let the two lines, B C and D E, if not parallel, meet in F; join A F; bisect the angle B F D, by the straight line F K; in F K, take any point, as G, and draw G H, perpendicular to B C; from G, with the distance G H, describe an arc, H I, cutting A F at I; join I G, and draw A K parallel to I G and K L parallel to G H; cutting B F at L; from K, with the radius K L, describe a circle L A M, which will be the circle required.

Problem XXV.—*To describe a circle that shall touch three straight lines,* A B, C D, E F, *provided all the three lines be not parallel.*

Figure 33.—Produce the lines, so that one of them, as C D, may meet the other two, A B and E F; and let the meeting of A B with C D, be at G, and of C D with E F at H; bisect the angles B G H and G H F by the straight lines G I and H I; from I, drop a perpendicular, I C, to any one of the three lines, C D; from I, with the distance I C, describe a circle, and it will touch the three straight lines A B, C D, E F, as required.

Problem XXVI.—*To describe a circle that may touch a straight line,* A B, *at a given point,* C, *and pass through another given point,* D.

Figure 34.—Draw C *f* perpendicular to A B; join C D, which bisect by a perpendicular, E *f*; from *f*, with the distance *f* C, describe a circle, which will be the circle required.

Problem XXVII.—*To describe a circle that shall touch a straight line,* A B, *at a given point,* E, *and another straight line,* B D, *provided that the two straight lines be not in the same straight line.*

Figure 35.—Make B *f* equal to B E; draw E G perpendicular to A B, and *f* G perpendicular to B D; from G, with the radius E G, or *f* G, describe the arc, H E *f* I, and it will touch A B at E and B D, as required.

Problem XXVIII.—*To describe an arc that shall touch a given circumference,* A B C, *and a straight line,* D E, *in a given point,* F.

Method I.—*Figure* 36. Draw F I perpendicular to D E; from F I, produced if necessary, cut off F G, equal to the radius of the circle A B C; join K G, which bisect by a perpendicular cutting F I at I; from I, with the radius I F, describe an arc, or circumference, A F H, which is the arc required.

Method II.—*Figure* 37. Draw F I perpendicular to D E, and A G parallel to F I; draw A F B and B I G; from I, with the distance I F, or I B, describe an arc, F B H, which is the arc required.

Problem XXIX.—*With a given radius,* G H, *to describe an arc or circumference that may touch a given arc or circumference,* C A B, *and pass through a given point,* D.

Figure 38.—From G H cut off G I, equal to the radius of the given circle; from F, with the distance I H, describe an arc; from D, with the distance G H, describe another arc, cutting the former at E; from E, with the distance E A or E D, describe an arc, G A D, and the problem is solved.

Problem XXX.—*In a given sector,* A B C D, *to inscribe a circle.*

Figure 39.—Bisect the angle B A D by A G C; draw E C F tangent to the circle; produce A B to E, and A D to F; bisect the angle E A F by A G, and the angles A E F by E G; from G, with the radius G C, describe a circumference, C H I, which is the solution required.

Problem XXXI.—*In a given circle to inscribe any number of equal parts.*

Divide the given circumference into as many equal parts as the number of inscribed circles: from the points of division, draw radii, and the circle will be divided into equal sectors; in any one of these sectors inscribe a circle by the last Problem; bisect the angle contained by each two radii; from the centre of the given circle, with the distance of the centre of the circle inscribed in the sector, describe a circumference, cutting the lines which bisect the sectorial angles; and the points so cut are the centres.

EXAMPLES.

Figure 40.—The given circle contains six equal inscribed circles.

Figure 41.—The given circle contains eight equal inscribed circles.

Figure 42.—The given circle contains twelve equal inscribed circles.

Problem XXXII.—*Any three straight lines* A B C, *being given, to find a fourth proportional.*

Figure 43.—Make any angle, as D E F; on the straight line E D, make E G equal to A, and E D equal to B; on the straight line E F, make E H equal to C; join G H; draw D F parallel to G H; and E F is the fourth proportional sought; or E G : E D : : E H : E F; that is, A : B : : C : E F.

N.B. When the lines B and C happen to be equal, the result or fourth term is called *a third proportional*; therefore, suppose B equal to C, then A : B : : B : E F. So that finding a third proportional is the same as finding a fourth, and may be considered as only a particular case of it; and in this construction E D and E H would be equal.

Problem XXXIII.—*To divide a straight line,* A G, *in the same proportion as another line,* A D, *is divided by the points* B *and* C, &c.

Figure 44.—Join D G; draw B E and C F parallel to D G, cutting A G at E and F; then will A G be divided by E and F, as A D is by B and C; or A E, E F, F G are to one another and to the whole A G, as A B, B C, C D are to one another and to the whole A D. In the same manner may any given line be divided into equal parts.

PROBLEM XXXIV.—*Between two straight lines,* A *and* B, *to find a mean proportional.*

Figure 45.—Draw the straight line C D E; make C D equal to A, and D E equal to B; bisect C E in *f;* from *f*, with the distance *f* C or *f* E, describe the semi-circle C G E; draw D G perpendicular to C E; and D G is the mean proportional required. Then C D : D G : : D G : D F; that is, A : D G : : D G : B.

PROBLEM XXXV.—*To divide a straight line,* A B C D, *harmonically in the given ratio of* I *to* K.

Figure 46.—Draw any straight line, as *e* A *g f;* make A *e* and A *f* each equal to I, and A *g* equal to K; join *f h* D; draw *g h* parallel to A D, and *h* C parallel to *e f;* join *h* B *e;* then A D : D C : : A B : B C.

PROBLEM XXXVI.—*Any three straight lines,* A B C, *being given, to describe a triangle, provided the sum of any two be greater than the third.*

Figure 47.—Draw the straight line D E equal to A; from D, with the distance B, describe an arc; and from E, with the distance C, describe another arc, cutting the former at F; draw D F and E F; and D E F is the triangle required.

PROBLEM XXXVII.—*Given the base,* A B, *of a triangle, the angle,* B A C, *and the ratio,* E *to* F, *of the other two sides, to describe the triangle, provided that* E *be to* F *in a greater ratio than the radius to the sine of the given angle* B A C.

Figure 48.—Make A *h* equal to E; from *h*, with the distance F, describe an arc, cutting A B at *i;* draw *i h*, and B C parallel to *i h;* and A B C will be the triangle required.

PROBLEM XXXVIII.—*To make a rectilinear figure equal and similar to a given rectilinear figure.*

RULE.—Divide the given rectilinear figure into triangles, by lines drawn from some one of its angles; take any one of its sides, and make a straight line in any situation equal thereto; upon the straight line thus posited, constitute a triangle, equal to the triangle on the corresponding line of the given figure; upon the side of the triangle which is to form a diagonal of the figure required, constitute another triangle, equal to the corresponding one of the given figure; proceed to form triangles on each succeeding diagonal in the same manner, till all the triangles are constructed; and the figure thus composed will be equal and similar to the given figure.

PROBLEM XXXIX.—*To make a quadrilateral equal and similar to a given one,* A B C D.

Figure 49.—Divide the given quadrilateral into two triangles, by the diagonal A C; make E F, equal to A B; and describe the triangle E F G, having its sides respectively equal to the triangle A B C; upon E G, as a base, describe another triangle, E G H, equal to A C D; and the quadrilateral E F G H is equal and similar to the given one, A B C D, as required.

PROBLEM XL.—*To make a rectilinear figure similar to a given one,* M N O P Q, &c., *upon a given straight line,* A B; *the extremity,* A, *being given, but unlimited towards* B.

Figures 50 *and* 51.—From the extremities, M, of the side of the given figure, corresponding to the given point, A, draw diagonals to every angular point; cut off a part, A *n*, equal to the corresponding side, M N, of the given figure; upon A *n* construct a figure, A *n o p q*, &c., equal and similar to the given figure, M N O P Q, &c., by the preceding problem; from A B cut off A D equal to the side of the rectilinear figure to be described; draw D E parallel to *n o*, cutting the diagonal A E at E; draw E F parallel to *o p*, cutting the diagonal A F at F; proceed in this manner to draw each successive side parallel to the corresponding side of the figure constructed; from the extremity of the last diagonal, cut the next diagonal, and from the last diagonal, in the same manner, to the other side, adjoining the given point A; and the figure A D E F G, thus constructed, will be similar to the figure M N O P Q, &c. as required.

PROBLEM XLI.—*Given two adjoining sides,* A B, B C, *of a parallelogram in position and magnitude, to describe the parallelogram.*

Figure 52.—From C, with the opposite side A B, describe an arc; from A, with the opposite side B C, describe another arc, cutting the former at D; join A D and D C, and A B C D is the parallelogram required.

N.B. If the angle C B A be given in quantity, but not in position, make it equal to the given angle by Problem VI.

PROBLEM XLII.—*Given two sides,* A *and* B, *of a rectangle, to describe the rectangle.*

Figure 53.—Draw a straight line, C D, equal to A; draw C F perpendicular to C D; and make C F equal to B; then proceed as in the last Problem, and the parallelogram C D E F will be the rectangle required.

PROBLEM XLIII.—*Given the diagonal,* A B, *of a rectangle, and one of the sides, not exceeding the diagonal, to describe the rectangle.*

Figure 54.—On the diagonal A B, describe the circumference A C B D A; make the chords A C and B D equal to the given side; join A D and B C; and A D B C A is the rectangle required.

Figure 55.—If the rectangle be a square, bisect the diameter A B by another, C D; and draw the four equal chords, which will form the square required.

PROBLEM XLIV.—*To make a triangle equal and similar to a given trapezium,* A B C D.

Figure 56.—Draw the diagonal B D, and draw C E parallel to B D, meeting the side A B produced at E; join D E, and A D E will be the triangle required.

PROBLEM XLV.—*To make a triangle equal to any given right-lined figure,* A B C D E.

Figure 57.—Produce A B on both sides of its extremities towards F and G; draw the diagonals A D and B D; through E draw E F, parallel to A D; and through C draw C G parallel to B D; join D F and D G, then D F G is the triangle required.

PROBLEM XLVI.—*To reduce a triangle,* A B C, *to a rectangle.*

Figure 58.—Bisect the altitude C G in D; through D draw E F parallel to A B, and from B draw B F perpendicular to A B; draw A E and B F perpendicular to A B; then A B F E will be the triangle required.

PROBLEM XLVII.—*To make a rectangle, having a side equal to a given straight line,* A B, *equal to a given rectangle,* C D E F.

Figure 59.—Produce the sides C F, D E, F E, and C D of the rectangle; make E G equal to A B; through G draw L H parallel to F E, cutting C F produced at L; draw L E, the diagonal, which produce to cut C D at K; draw K H parallel to E G, and E I H G will be the rectangle required.

PROBLEM XLVIII.—*To make a parallelogram with a given angle equal to a given parallelogram,* A B C D.

Figure 60.—Make the angle B A E equal to the given angle, and let A E cut C D, produced if necessary at E; draw B F parallel to A E, cutting D C at F; then will the parallelogram A B F E be equal to the given parallelogram, A B C D.

PROBLEM XLIX.—*To make a square equal to a given rectangle,* A B C D.

Figure 61.—Produce A B, the side of the rectangle, and make B E equal to B C; bisect A E in I; on I, as a centre, with

the radius I E or I A, describe a semicircle, A H E; produce the other side, C B, of the rectangle, to cut the circle in H; describe a square, B H G F, upon B H; then B H G F is the square required.

PROBLEM L.—*To make a square equal to two given squares.*

Figure 62.—Let A and B be the two given squares. Construct the right-angled triangle *c a b;* let one of the sides, *c a*, containing the right angle, be equal to the side of the square, A; and let the other, *a b*, be equal to the side of the square B. On *c b*, describe the square C, which is the square required.

In the same manner may a circle be made equal to two given circles; for, if *c a*, *a b*, be considered as diameters, or radii of the two given circles, *c b* will be a diameter or radii of a circle, equal in area to them both: and also in the same manner, if two similar rectilinear figures be given, a rectilinear figure may be found similar to either, and equal to both; for, if *c a* and *a b* be considered as homologous sides, that is, those which are opposite to the equal angles, *c b* will be the homologous side of the figure required.

PROBLEM LI.—*To make a square equal to three given squares.*

Figure 63.—Let A, B, C, be three given squares. Make a right angle, *c a b;* let *a c* be equal to the side of the square A, and *a b* equal to the side of the square B; join *b c*, and it will be the side of a square equal to A and B. Draw *b d* perpendicular to *b c*, and make *b d* equal to the side of the remaining square C; join *d e*, and it will be the side of a square equal to the three given squares, A, B, C, as was required.

From this process, it is evident that a square may be found equal to any given number of squares, by first finding one equal to any two of them, and then another equal to the square found, together with one of the remaining squares; then find another equal to the square last found, together with one of the other remaining squares; and so on, till all the squares are made use of, and the last square found will be equal to all the given squares.

SCHOLIUM.—It frequently happens in the description of the segment of a circle, when the height of the segment is very small in proportion to the chord, that there is no room to find the centre; the following problems show how to describe the arc without finding the centre:

PROBLEM LII.—*Having the chord and height of the segment of a circle, to describe the segment without finding the centre.*

Figure 64.—First Method.—Let A B be the chord of the segment, and C D its height; join D A and D B; make an instrument, E F G, so that the angle E F G may be equal to the angle A D B, and the sides F E and F G at least equal to the chord A B; put a pin at A, and another at B; slide the instrument along the pins, keeping the side F E close to the pin A, and F G to the pin B; a pencil being held at the angular point F will describe the arc A F B, as was to be done.

Figure 65.—Second Method.—Join D B, and draw D H parallel to B A; make an instrument, E F G, so that the angle E F G may be equal to the angle H D B, and the sides E F and E G at least equal to the half chord D B; put pins in the points A and D, and sliding the instrument along them, a pencil at F will describe half of the arc; and by moving the pin out of A, and putting it in B, the other half will be described in the same manner.

The former of these Problems depends on *Prop.* XXI. b. iii. *Euclid*, viz., that all the angles in the same segment of a circle are equal; and the latter, on *Prop.* XXXII. b. iii. *Euclid*, viz., that if a straight line touch a circle, and from the point of contact a straight line be drawn, cutting the circle, the angles made by such line with the line touching the circle, will be equal to the angles in the alternate segments.

Either of these instruments, in the description of flat segments, may be applied occasionally; but the latter, by reason of the obtuseness of the angle, slides with less friction along the pins, takes up much less room, and can be applied in any cases where it is impossible to use the other.

N.B.—If C D is very small, the instrument may be made in one piece.

Besides the methods here shown for the description of the segment of a circle from the rules of geometry, the following arithmetical rule will be found eligible on many occasions, particularly, where there is a want of a floor to draw the lines upon, or a want of space at the ends of the curve.

RULE.—Divide the square of the half chord by the versed sine, or height of the segment; add the height of the segment to the quotient; then half the sum is the radius of the circle.

EXAMPLE.—Suppose the chord of the segment of a circle to be 24 feet, and the versed sine or rise of the segment 5 feet; the radius of the circle is required.

```
2) 24
   ——
   12 half chord.
   12
   ———
5) 144
   ———
   28.8
    5
   ———
2) 33.8
   ———
   16.9 the radius required.
```

This is derived from *Prop.* XXXV. b. iii. *Euclid*, where it is shown, that if two straight lines in a circle cut each other, the rectangle under the segments or parts of the one, is equal to the rectangle of the segments of the other; and consequently, if the segments of one of the lines be equal to each other, the rectangle under the parts of the other line will be equal to the square of either part of the line, which is divided equally; but the contents of a rectangle, divided by one of its sides, gives the other side; or the area of the square, which is equal to the rectangle, being divided by the given side of the rectangle, gives the other side of the rectangle; and adding the versed sine, gives the diameter.

The method of dividing the circumference of a circle into any number of equal parts, or to inscribe any polygon therein, according to the approximation of Renaldinus, will be found under the article CIRCLE, Figure 5.

The various methods of describing the ellipsis upon a plane, will be found under the article ELLIPSIS; but, besides what is there shown, the following problems, concerning this curve, will also be found necessary in the art of perspective delineation.

PROBLEM LIII.—*Given the trapezium,* A B C D, *and a point,* E, *in one of the sides, to find a point in each of the other sides, so that if an ellipsis were to be inscribed, it would touch the trapezium in those points.*

Figure 66.—Produce the sides of the trapezium till they meet at K and L; then draw the diagonals A C and B D, cutting each other at F; produce B D, till it cut K L, at M. Through F, and the given point E, draw E G, cutting B C

at G; and from M, through the points E and G, draw M H and M G, cutting the other two sides in the points I and H, then E, H, G, I, will be the four points required.

PROBLEM LIV.—*A trapezium,* A B C D, *being given, and a point,* E, *in one of the sides, to find the centre of an ellipsis that may be inscribed in the trapezium, and pass through the point of contact,* E, *without drawing any part of the ellipsis.*

Figure 67.—Find the points of contact H, G, I, E, as in the last Problem. Join the points G and E, by the right line G E; bisect it in M, and from K, where the opposite sides A D and B C meet, and through the point M, draw K M indefinitely; also join any other two points of contact, as H I; bisect H I and N from L, where the opposite sides B A and C D meet; draw L N, meeting K M at P; then P will be the centre of the ellipsis required.

In like manner, if the points G and H were joined, and bisected at Q, and a line being drawn from B, where the opposite sides A B and C B meet, through Q, it would also meet in P, the centre, &c.

PROBLEM LV.—*Given a trapezium,* A B C D, *and a point,* E, *in one of the sides, to find the two axes of an ellipsis that may be inscribed in the trapezium, and pass through the point,* E, *without drawing any part of the ellipsis.*

Figure 68.—Find the opposite points of contact, H, E, F, G, by Problem LIII.; from thence, find the centre, P, by the last Problem. From E, and through the centre P, draw E M, making P M equal to P E; and through H or any other point of contact, draw H K, parallel to D C, cutting E M at K; then K H is an ordinate to the diameter E M. Through P, the centre, draw P R parallel to H K; then find the extremities, R and S, of the diameter R S, by Problem 3, of ELLIPSIS. The conjugate diameters, E M and R S, being now found, then find the two axes, V W and X Y, by Problem 4, of ELLIPSIS.

GIBLEA CHEQUE, GIBLE CHECK, or JIBLET CHEEK, a recess made by cutting away the right angle formed by the front and returns of the aperture of a stone door-case, in the form of a rebate or reveal, so as to make the outside of the door, or closure, flush with the face of the wall. The term is used by stonemasons in Scotland.

GIGANTIC ORDER, a name given by Scamozzi to the Tuscan order.

GILDING, the art of applying to various substances an extremely thin coating of gold. If the substances to be gilt be metallic, this is effected by simple adhesion of the surfaces, but if not, the gold is attached by means of some adhesive medium. The use of gilding in the ornaments and decorations of an apartment, adds greatly to the richness of its appearance, but unless applied judiciously, and sparingly, it is apt to have a tawdry effect, most offensive to good taste.

GILL, a measure, the fourth part of a pint. The imperial gill now in use contains 8.6648125 cubic inches.

GIMLET, or GIMBLET, (from the French) a piece of steel of a semi-cylindrical form, hollow on one side, having a cross handle at one end, and a worm or screw below at the other: its use is to bore a small hole in a piece of wood. The screw draws the instrument forward into the wood while it is turned by the handle, and the excavated part, forming a sharp angle with the exterior, cuts the fibres across, and contains the core of wood cut out.

GINÆCONITES, (Greek) apartments in the surrounding porticos of the Greek houses, which contained the family rooms tricliniums and cubiculums. *See* HOUSE.

GIOCONDO, an architect, who flourished in the sixteenth century, was a native of Verona, where he first taught languages for a subsistence, and was also well qualified in mathematical learning. On visiting France, he was employed to build two bridges over the Seine. He very soon afterwards obtained the title of architect royal to the French king, but did not live long after; the exact period of his death is uncertain. He published several works which did him much credit as a writer, and extended his fame as an artist. Amongst others, an edition of Pliny's *Epistles*, and a correct edition of Vitruvius, illustrated with figures, the latter he dedicated to Pope Julius II. He assisted in editing many other works of the ancients, and was the first person who gave a design for Cæsar's bridge over the Rhine. In 1506, he wrote four dissertations, addressed to the magistracy of Venice, concerning the waters of that city. He was employed with Raphael and San Gallo, in superintending the erection of St. Peter's. His last work was probably the rebuilding of the stone bridge at Verona.

GIRANDOLE, (Italian) a chandelier; a large kind of branched candlestick.

GIRDER, (from the Saxon) a large beam, either of one entire piece, or consisting of several, in order to shorten the joists of a floor, which would otherwise have too great a bearing.

When girders are made double, they should be turned the contrary way to that in which they were sawn, that the stronger end may support the weaker. If it be found necessary to truss girders, the truss should be similar to that of a roof. The best form of girder for floors of moderate dimensions, consists of two braces and a straining piece, having one-third of the whole length, excepting the part at each end, which is necessary for the butment or wall-hold.

The two braces are strained by means of queen-bolts, and resisted at the other end by iron butments, which are formed to the same section as the braces, and are made to go through on each side, so as to have a bolt at either end; the braces and straining piece being let into each beam.

When girders have a very great bearing, and have only the depth of a single piece, it is well known that the strain at the joggles and abutments is prodigious: girders of long bearing should therefore be made into two flitches, one above the other, and braced as above.

By this plan, the depth allowing of an upper and lower beam, the girder will be infinitely more stiff than one of the depth of a single piece, and consequently more able to support the naked flooring and boarding.

No summers or girders should be over the heads of doors or windows.

No summer or girder should lie less than ten inches into the wall; nor joists less than eight inches.

The ceiling joists ought to be framed about half an inch below the girder, and the girder ought to be furred to the level of the ceiling joists.

Girders ought to be made of heart wood, as free from knots as possible, because they destroy the continuity of the fibres, and impair the strength of the girder.

The following rules for finding the scantlings, are given by Tredgold in his *Elementary Principles of Carpentry*.

"*Case* 1.—To find the depth of a girder when the length of bearing and breadth of the girder are given.

"*Rule.*—Divide the square of the length in feet, by the breadth in inches; and the cube root of the quotient multiplied by 4.2 for fir, or by 4.34 for oak, will give the depth required in inches.

"*Case* 2.—To find the breadth when the length of bearing and depth are given.

"*Rule.*—Divide the square of the length in feet, by the cube of the depth in inches; and the quotient multiplied by 74 for fir, or by 82 for oak, will give the breadth in inches.

"*Example to Case* 2.—Let the bearing be 20 feet, and the depth 13 inches; to find the breadth, so that the girder shall be sufficiently stiff.

The cube of the depth is 2197, and the square of the length is 400; therefore $\frac{400}{2197} \times 74 = 13.47$ inches, the breadth required.

"In these rules, the girders are supposed to be 10 feet apart, and this distance should never be exceeded; but should the distance apart be less or more than 10 feet, the breadth of the girder should be made in proportion to the distance apart.

"When the bearing exceeds about 22 feet, it is very difficult to obtain timber large enough for girders; and it is usual, in such cases, to truss them. The methods in general adopted for that purpose, have the appearance of much ingenuity; but in reality, they are of very little use. If a girder be trussed with oak, all the strength that can possibly be gained by such a truss, consists merely in the difference between the compressibility of oak and fir, which is very small indeed; and unless the truss be extremely well fitted at the abutments, it would be much stronger without trussing. All the apparent stiffness produced by trussing a beam, is procured by forcing the abutments, or, in other words, by cambering the beam. This forcing, cripples and injures the natural elasticity of the timber; and the continual spring from the motion of the floor, upon parts already crippled, it may easily be conceived, will soon so far destroy them as to render the truss a useless burden upon the beam. This is a fact that has been long known to many of our best carpenters, and which has caused them to seek for a remedy in iron trusses; but this method is quite as bad as the former, unless there be an iron tie as an abutment to the truss; for the failure of a truss is occasioned by the enormous compression applied upon a small surface of timber at the abutments. The defects of ordinary trussed girders are very apparent in old ones, as it is not simply strength that is required, but the power of resisting the unceasing concussions of a straining force, capable of producing a permanent derangement in a small surface at every impression." Girders of wrought and cast iron are now used extensively in railway and canal works, for bridges, &c.

GIRDING BEAM. *See* GIRDER.

GIRDLE, (from the Saxon) a circular band or fillet surrounding a part of a column.

GIRT, the same as FILLET, which see.

GIRT, in timber measure, according to some, the fourth part of the circumference, and is generally taken for the side of a square, equal in area to the section of the tree cut through where the perimeter is taken in order to obtain the girt.

GIVEN DATUM, a term frequently used in mathematics, signifying a thing supposed to be known, whether in position or magnitude; which is accordingly said to be *given in position*, or *in magnitude*, or both, as one or the other, or both, are known.

GLACIS, (French) an easy slope or declivity.

GLASS, (from the Saxon, *glaes*) a hard, brittle, transparent factitious substance, formed by the fusion of silicious matter, such as powder flint or fine sand, blended with alkaline earth, metallic oxide, and other substances. In building, glass is used in thin transparent plates for windows, which admit light, while they exclude wind and rain.

The time at which glass was invented, is very uncertain. "It was known," says Dr. Ure, "to the Phenicians, and constituted for a long time an exclusive manufacture of that people, in consequence of its ingredients, (natron, sand, and fuel,) abounding upon their coasts. It is probable that the more ancient Egyptians were unacquainted with glass, for we find no mention of it in the writings of Moses. But, according to Pliny and Strabo, the glass-works of Sidon and Alexandria were famous in their times, and produced beautiful articles, which were cut, engraved, gilt, and stained of the most brilliant colours, in imitation of precious stones. The Romans employed glass for various purposes; and have left specimens in Herculaneum, of window-glass, which must have been blown by methods analogous to the modern. The Phenician processes seem to have been learned by the Crusaders, and transferred to Venice in the 13th century, where they were long held secret, and formed a lucrative commercial monopoly. Soon after the middle of the 17th century, Colbert enriched France with the blown mirror glass manufacture."

The application of glass to the glazing of windows, is of comparatively modern introduction, at least in northern and western Europe. In 674, artists were brought to England from abroad to glaze the church windows at Wearmouth in Durham; and even in the year 1567, this mode of excluding cold from dwellings was confined to large establishments, and by no means universal even in them. An entry then made, in the minutes of a survey of Alnwick Castle, the residence of the Duke of Northumberland, informs us that the glass-casements were taken down during the absence of the family to preserve them from accident. A century after that time, the use of window-glass was so small in Scotland, that only the upper rooms in the royal palaces were furnished with it, the lower part having wooden shutters to admit or exclude the air.

At an early period of its history in this country, the glass-manufacture became an object of taxation, and duties were from time to time imposed on it, which operated most injuriously, not only on the manufacture itself, but on building generally, by preventing the more extensive use of so ornamental an article. Within the last few years, however, a more enlightened policy has prevailed; and so great a reduction of the duties on glass has been granted, that an enormous increase in the manufacture and use of it has taken place. The result is seen in the improved appearance of our dwelling-houses, in the great superiority of the quality of the glass used at present, and in the magnificent plate-glass windows now so generally adopted in shop-fronts.

Of the glass used in building, there are three qualities in common use, denominated *best*, *second*, and *third*. The best is that which is of the purest metal, and free of blemishes, as blisters, specks, streaks, &c. The second is inferior, from its not being so free of these blemishes. The third is still inferior, both in regard to quality and colour, being of a greener hue. They are all sold at the same price per crate, but the number of tables is different, according to the quality: best, 12 tables; second, 15 tables; third, 18 tables.

These tables are circular when manufactured, and about four feet in diameter; in the centre is a knot, to which, in the course of the process, the flashing rod was fixed, but, for the safety of carriage and conveniency of handling, as well as utility in practice, a segment is cut off, about four inches from the knot: the large piece with the knot, still retains the name of *table*, the smaller piece is technically termed *a slab*. From these tables being of a given size, it is reasonable to suppose that when the dimensions of squares are such as cut the glass to waste, the price should be advanced.

Crown glass is the best description of window-glass. It is made without any mixture of metallic oxide, and is both specifically lighter, and much harder, than flint glass. Broad glass is an inferior kind of window-glass, made with a cheaper kind of alakli. Plate-glass is superior in quality and in appearance to all other glass. From the quantity of metal it contains, it must be almost, if not altogether, colourless—that sort which is tinged, being of an inferior quality. It is

both blown and cast. Plates which are blown are limited in dimensions, while those that are cast are made of very great size, the limit being caused by the expensiveness of the machinery required for the management of very large masses of the material. Plate-glass is necessarily costly, because of the numerous and laborious operations which it undergoes, and of the risks of fracture while subjected to them. In sashes it has a magnificence peculiar to itself; objects seen through it are not distorted; and objects seen in it, have the same fair appearance. It is now made of very large dimensions.

Glass has also been introduced as a material for the manufacture of pipes. Mr. James Hartley, of Bishopwearmouth Glass Works, has, after extensive experiments, succeeded in establishing the practicability of making glass pipes, suitable for the conveyance of gas or water, and has, it is also said, proved that pipes, stronger than the ordinary metal ones, and much cheaper, may be made of glass.

A still more novel application of this material is noticed in *The Builder*, viz., the importation from Antwerp of a small parcel of glass-tiles. These tiles are similar in form to the common clay-tile for roofing buildings, the advantage held out being their lightness, and being pervious to the rays of the sun. The latter quality is presumed to render them suitable for the roofs of green-houses, as they will not interrupt the heat and light, whilst they are sufficiently strong to resist the effects of hail-storms, which will much reduce the cost of insurance on green-houses. They have the appearance of the common green glass, they vary in price from eleven to sixteen shillings per dozen, according to their thickness and weight. *See* STAINED GLASS.

GLAZING, the business of the glazier, consisting in fitting glass in sashes, frames, and casements, and fixing it either in putty or lead.

It may be classed under the denominations following:—*Sash-work*, *lead-work*, and *fret-work*.

The tools necessary for sash-work are, a diamond, a ranging-lath, a short-lath, a square, a rule, a glazing-knife, a cutting chisel, a beading hammer, duster, and sash-tool; and in addition, for stopping-in squares, a hacking knife and hammer. The diamond is a speck of that precious stone, polished to a cutting point, and set in brass in an iron socket, to receive a wooden handle, which is so set as to be held in the hand in the cutting direction; the top of the handle goes between the root of the fore-finger and middle-finger, and the under part, between the point of the fore-finger and thumb; there is, in general, a notch in the side of the socket, which should be held next the lath. *See* DIAMOND.

Some diamonds have more cuts than one.

Plough diamonds have a square nut on the end of the socket next the glass, which on running the nut square on the side of the lath, keeps it in the cutting direction. Glass benders have these plough diamonds without long handles, as, in cutting their curious productions, they cannot apply a lath, but direct them by the point of their middle finger gliding along the edge of the glass. The ranging lath must be long enough to extend rather beyond the boundary of the table of glass. Ranging of glass, is the cutting it in breadths, as the work may require, and is best done by one uninterrupted cut from one end to the other. A short lath is applied to stripping the square to suit the rebate of a sash; as in ranging, they are generally cut full. A square is used in cutting the squares from the range, that they may be more certainly cut at right angles. The carpenter's chisel is used in paring away some of the rebate of the sash, when the glass does not lie so flat as to allow a proper breadth for front putty. The glazing knife is used for laying-in the putty in the rebates, for bedding-in the glass, and for finishing the front putty. A bradding-hammer is made with a head in the form of a small parallelopiped, with a socket for the handle, rising at an obtuse angle from the middle of one of its sides; the square edges of the head drive the brads in a horizontal position, and is less liable to accident than if performed by another tool: some use the basil of the chisel.

Brass points are esteemed the best; small cut brads are also used. All new work should be bradded, to prevent the glass being moved out of its bed.

The duster is used in brushing up the front pulleys, and taking off the oil from the glass. The sash-tool is used in taking off the oil from the inside, after the back pulleys are cleaned off, and is generally used wet. The hacking-knife is for cleaning out the old putty from rebates, where squares are to be stopped in. The use of the rule needs no explanation.

N.B.—Glaziers' rules are two feet long, in four different pieces. Lead-work is used in inferior offices, and is in general practice throughout the country.

Frames are made to receive these lights, with bars across, to which the lights are fastened by leaden bars: these bars are called *saddle bars*, and where openings are wanted, a casement is introduced, either of wood or iron. Sometimes a sliding frame answers the same purpose. Church windows are in general made in this manner, in quarries or in squares. The tools which this work, in addition to the former, require, are these: a vice, with different cheeks; and cutters, to turn out the different kinds of lead, as the magnitude of the window or the squares may require.

In common there is broad and narrow lead. The German vices are esteemed the best, and turn out a variety of lead in different sizes.

There are moulds belonging to these vices, in which bars of lead are cast; in which form the mill receives them, and turns them out with two sides parallel to each other, and about three-eighths of an inch broad, with a partition connecting the two sides together, about an eighth of an inch wide, forming, on each side, a groove nearly $\frac{3}{16}$ by $\frac{1}{8}$ of an inch, and about six feet long.

The remainder of the tools, besides a vice and moulds, are, a setting-board, a latterkin, setting-knife, rosin-box, tin, glazing-irons, and clips.

The setting-board is that on which the ridge of the light is marked and divided into squares, and struck out with a chalk line, or drawn with a lath, which serve to guide the workman. One side and end are squared, with a projecting bead or fillet.

The latterkin is a piece of hard wood, pointed, and so formed as to clear the groove of the lead, and widen it for the more readily receiving the glass.

The setting-knife is a blade with a round point, loaded with lead at the bottom of the blade, with a long square handle. The square end of the handle serves to force the squares home tight in the lead; being loaded with lead, it is of greater weight, and also cuts off the ends of the lead with greater ease, as, in the course of working these lights, the lead is always longer than necessary, till trimmed.

The rosin-box contains powdered rosin, which is put on all the joints previous to soldering.

Tin is for preparing the glazing before soldering.

The clips are for holding the irons.

All the intersections are soldered on both sides, except the outside joints of the outer side, *i. e.* where they come to the outer edge. These lights should be cemented, which is done by thin paint being run along the lead bars, and the chasm filled with dry whiting, and after it has stood a short time, till the oil is secreted a little, a small quantity of dry red or

white lead is dusted over it again; it then dries hard, and will resist the weather well.

Fret-work is the ornamental part, and consists of working ground and stained glass, in fine lead, into different patterns. In many cases, family arms and other devices are worked in it. It is a branch capable of great improvement, but at present neglected.

Old pieces are very much esteemed, and valued high. The same expense would, doubtless, were it not for prejudice, furnish elegant modern productions. They are placed in halls, and stair-case windows, or in some particular church windows; in many instances, they are introduced where there is an offensive aspect in a place of particular or general resort.

Glaziers clean windows; and in London it is a great part of their work.

GLOBE, (French) a spherical body, more usually called a sphere. *See* SPHERE.

GLUE, (from the French) a tenacious viscid matter, made of the skins of animals, for cementing two bodies together.

Glue is bought in cakes; and is better, as the skin of the animal from which it is made is older: that which swells much when steeped in water, without dissolving in it, is of the best quality.

To prepare glue; break the cakes into small fragments of convenient size: soak them in as much water as will just cover them; after it has remained about twelve hours, boil the whole in a copper or leaden vessel, over a gentle fire, till the glue is dissolved in the water, stirring it constantly with a wooden stick: it should then be poured through a sieve, to separate it from the scum and other filth: and lastly, it should be boiled over a smart fire, and put into a wooden vessel, in which it is to remain for use.

To make good glue for external work: grind as much white lead with linseed oil as will just make the liquid of a whitish colour, and strong but not thick; and it will then be fit for use.

The following is given by Mr. Clennel as a good method of making glue. The materials above enumerated are "first digested in lime-water, to cleanse them from grease or dirt; they are then steeped in clean water with frequent stirring, and afterwards laid in a heap, and the water pressed out. They are then boiled in a large brass cauldron with clean water, scumming off the dirt as it rises, and it is farther cleansed, by putting in, after the whole is dissolved, a little melted alum, or lime, finely powdered. The scumming is continued for some time, after which the mass is strained through baskets, and suffered to settle, that the remaining impurities may subside. It is then poured gradually into the kettle again, and farther evaporated by boiling and scumming, till it becomes of a clear dark-brownish colour. When it is thought to be strong enough, it is poured into frames or moulds about six feet long, one broad, and two deep, where it gradually hardens as it cools, and is cut out when cold by a spade into square cakes. Each of these is placed in a sort of wooden box, open in three divisions to the back; in this, the glue, while yet soft, is cut into three slices, by an instrument like a bow, with a brass wire for its string. The slices are then taken out into the open air, and dried on a kind of coarse net-work, fastened in moveable sheds, four feet square, which are placed in rows in the glue-maker's field. When perfectly dry and hard, it is fit for sale."

Mr. Austin, of Hatton Garden, some time since, took out a patent for "*a new method of glueing or cementing certain materials for building and other purposes.*" The mode of manufacture and applying it, is thus described in the specification:—

"The cement used by the patentee is made by mixing India-rubber with cold naphtha, in the proportion of eight

ounces of India-rubber cut into small pieces, to each gallon of naphtha, stirring it from time to time, until the India-rubber is dissolved; then, to one part, by weight, of this mixture two parts of lac are added, and the whole is thoroughly blended together by the application of heat, accompanied with occasional stirring. When greater elasticity is required, a larger proportion of the India-rubber solution is used; if greater hardness is necessary, a larger proportion of lac is employed; and where the India-rubber would be liable to injury from great exposure and pressure, a much less proportion is used, and it is sometimes dispensed with altogether; asphalte, pitch, or resin, or other materials of that nature, may in some instances be substituted for the lac.

The materials for building-purposes to which this cement is applied are, slate, tiles, stone, glass, and metal-plates. When being used, the cement is kept in a heated state in a dish or vessel containing a narrow trough, termed a stamper, which slides up and down therein between guides; the slate or other material is brought to the heat of 150 degrees Fahrenheit, and placed upon the dish, and the stamper being then raised, imprints or stamps a margin of cement thereon. The requisite margins of cement for forming overlapping joints being thus applied to the slate or other material, the cemented portions or margins are laid in contact with each other, and in a short time become firmly united, forming water-tight surfaces. Sometimes, to expedite the process, a coating of naphtha, or other spirit that will act upon the cement, or a solution made by dissolving the cement in naphtha or other spirit, is applied to the cemented portions, or margins. The cement may also be used for securing the above materials to the building, as well as to each other."

"The patentee connects pieces of glass together with the above cement when making skylights, conservatories, frames for horticultural purposes, &c.; he also cements slate, stone, metal, and manufactured clays and cements, together, or to wood, or to woven and other fabrics, to wood for building or other purposes; he likewise cements pieces of leather for making boots and shoes, and hose or pipes for fire-engines; also leather and cork together, or to wood, metal, or woven or other fabrics, and woven and other fabrics to wood, for the manufacture of trunks, portmanteaus, packing cases, and other purposes. When joining these materials, the parts must be dry and free from dust, and should be warmed previous to receiving a coat of the cement, in order that it may not be chilled at the moment of application. If the joint is to be made at once, the parts must be expeditiously put together and pressed, as the cement rapidly loses its heat, and becomes solidified, but the junction may be effected at any subsequent period by the application of heat, or the spirit or solution before described."

GLYPH, any canal or cavity used as an ornament; hence the tablets in the frieze of the Doric order are called *triglyphs*, from their having three vertical channels; that is, two whole ones and a half one at each edge of the triglyph.

GNEISS, is the name of one of the great mountain formations, being reckoned the oldest of the stratified rocks. It is composed of the same substances as granite, viz.: quartz, mica, and feltspar. In gneiss, however, they are not in granular crystals, but in scales, so as to give the mass a slaty structure. It abounds in metallic treasures.

GOBELIN, the term applied to the celebrated tapestry, introduced into France by the brothers Gobelin. In the year 1677, Colbert purchased the dye-houses from the Gobelin family, in virtue of an edict of Louis XIV., styled it the *Hotel Royal des Gobelins*, and established on the ground a great manufactory of tapestry, similar to that of Flanders. The celebrated painter Le Brun was appointed director-in-

chief of the weaving and dying patterns. Under his administration were produced many magnificent pieces of tapestry, which have ever since been the admiration of the world; such as Alexander's battles, the four seasons, the four elements, and the history of the principal events in the reign of Louis XIV. There is an academy within the Gobelins for the instruction of youth in the various branches of the fine arts, in physical science, and mechanics, subservient to the improvement of the manufacture.

GNOMONIC COLUMN, *See* COLUMN.

GNOMONIC PROJECTION OF THE SPHERE, that in which the eye is situated in the centre of the sphere, and projects all the circles upon a plane touching its surface.

It is evident, that in this projection, all the great circles of the sphere are projected into straight lines, since they all pass through the centre of the sphere. Every lesser circle parallel to the plane of projection is projected into a circle, and any lesser circle not parallel to the plane of projection, is projected into one of the conic sections.

A very excellent tract upon the projection of the sphere, by Mr. Emerson, contains the full theory of the gnomonical projection.

GOCCIOLATOIO, *See* CORONA.

GOLA, GOLA-DIRETTA, GOLA-ROVESCIA, *See* CYMATIUM.

GOLDMAN, an architectural writer, as also a mathematician, born at Breslaw, in Silesia, in the year 1623, and died at Leyden, 1665. He published his *Elementa Architectura Militaris*, 1643: another treatise of his, on the same subject, was published in 1696, accompanied with numerous engravings, and a life of the author.

GONIOMETER, (from γωνια, *an angle*, and μετρω, *I measure*) an instrument for measuring solid angles. A most convenient instrument for this purpose was invented by Dr. Wollaston.

GONIOMETRICAL LINES, lines used in order to determine the quantity of an angle. Such are the lines of sines, tangents, and secants, commonly placed upon plane scales, the sector, Gunter's scale, &c.

GORGE, (French) a concave moulding, much less recessed than a scotia, used chiefly on frames, chambranles, &c.

GORGE is sometimes used for the cyma recta. It is used for the neck of a column; but it is more properly called *collarino*, *gorgerin*, or *gorge*.

GORGERIN or GORGE, in architecture the little frieze in the Doric capital, between the astragal at the top of the shaft of the column, and the annulets. Some call it *collarino*. Vitruvius gives it the name of hypotrachelium.

GOTHIC ARCHITECTURE, a title generally understood in the present day to apply to that style of building in which the Pointed arch is the most prominent, though not the only characteristic. The term has been variously applied at different times, and by different writers, whether contemporaneous or otherwise; indeed, so great is the confusion on the subject, that it is not always easy to define the class of buildings alluded to under this title. Some authors include under the term all styles of building which differ from those adopted by the Greeks and Romans, embracing all modes of building which were in vogue from the decline of Classical architecture to its revival in the sixteenth century. Others limit the phrase to those modes which prevailed from the decline of Roman art to the introduction of the Pointed arch, including the Romanesque, Lombardic, Saxon, and Norman styles, in all of which the semi-circular arch was employed. A third class of writers apply the name solely to the Pointed style, under which restriction the term is for the most part employed in the present day, though some would still farther limit the application by adopting it solely for that division of Pointed architecture which is by most writers designated Pure or Decorated Gothic.

The term Gothic seems to have been first brought into use by the Italians, who applied it to all styles of building then prevalent which deviated from the Classic. Vasari, an Italian architect who lived at the commencement of the sixteenth century, after speaking of Greek orders, says, "there is another kind called Gothic (Tedesca) which differs materially both as to ornament and proportion from that of ancient and modern date. So deficient is it in systematic rules, that it may be deemed the order of confusion and inconsistency. The portals of this description of buildings, which has so much infested the world, are adorned with slender columns entwined like vine-branches, and unequal to sustain the weight, however light, which is placed above them. Indeed, the whole exterior, with its other decorations, its profusion of canopied niches raised above one another, with so many pyramids, leaves, and points, renders it apparently impossible, not only that they should be durable, but that it should support itself—giving the whole an air of being made of pasteboard rather than of stone and marble. This style was invented by the Goths, who spread the contagion through Italy. May God deliver every country in future from the adoption of plans, that substituting deformity for beauty, are unworthy of further attention."

From the description which he gives in this passage, it will be very reasonably inferred, that he refers to the Pointed style of architecture, but it is evident that he also includes the modes adopted on the decline of Roman art, for he cites, as examples, the palace of Theodoric at Ravenna, and the churches of St. John the Evangelist, and of St. Vitalis, in the same city, as also other buildings of Lombardic and Byzantine architecture. Amongst the first writers who introduced the term into England was, we believe, Evelyn, and he gives the following description:—"Gothic architecture," says he, "is a congestion of heavy, dark, melancholy, monkish piles, without any just proportion, art, or beauty;" and elsewhere he describes it as "a fantastical light species of building." Sir Christopher Wren confirms the use of this term, for, after describing edifices erected after this mode of building as "mountains of stone, vast gigantic buildings, but not worthy the name of architecture," he says, "This we now call the Gothic manner; so the Italians called what was not after the Roman style." In another place our author applies the term *Saracenic* to buildings in the Pointed style, supposing that form of arch to have been brought from the East by the Crusaders. But to show what vague notions he held upon the subject, we must add, that he attributes the cathedral of Winchester, and the church of St. Cross, to a period preceding the Norman conquest. Warton's ideas upon this head must have been also very indefinite, for he makes his earliest division of the style to commence about A. D. 1200, which he calls *Gothic Saxon*, as distinguished from the true Gothic, of which he makes tracery in the window-heads the chief characteristic. He even denies the title of Gothic to Salisbury cathedral, which he includes under the term Gothic Saxon. Bishop Warburton gives the name of *Norman* to Pointed architecture, reserving that of *Saxon* for those styles in which the semi-circular arch prevailed.

Captain Grose, a few years later, adverting to the use of the title in question, says, "Most of the writers who mention our ancient buildings, particularly the religious ones, notwithstanding the striking difference in the styles of their construction, class them all under the common denomination of Gothic; a general appellation, by them applied to all buildings not exactly conformable to some one of the five orders of architecture. Our modern antiquaries more accurately

divide them into Saxon, Norman, and Saracenic; or that species vulgarly, though improperly, called Gothic."

Mr. Bentham, a cotemporary, remarks upon the same subject as follows:—"The term Gothic, applied to architecture, was much used by our ancestors in the last century, when they were endeavouring to recover the ancient Grecian or Roman manner; whether they had then a retrospect to those particular times when the Goths ruled in the empire, or only used it as a term of reproach to stigmatize the productions of ignorant or barbarous times, is not certain; but I think they meant it of Roman Architecture: not such certainly as had been in the age of Augustus, but such as prevailed in more degenerate times, when the art itself was almost lost, and particularly after the invasion of the Goths: in which state it continued many ages without much alteration. Of this kind was our Saxon and earliest Norman manner of building, with circular arches and strong massive pillars, but really Roman architecture, and so was called by our Saxon ancestors themselves. Some writers call all our ancient architecture, without distinction of round and pointed arches, Gothic; though I find of late the fashion is to apply the term solely to the latter, the reason for which is not very apparent. The word Gothic, no doubt, implies a relation some way or other to the Goths; and if so, then the old Roman way of building with round arches above described, seems to have the clearest title to that appellation; not that I imagine the Goths invented or brought it with them; but that it had its rise in the Gothic age, or about the time the Goths invaded Italy. The style of building with pointed arches is modern, and seems not to have been known in the world till the Goths ceased to make a figure in it. Sir Christopher Wren thought this should rather be called the Saracen way of building; the first appearance of it here was certainly in the time of the Crusades; and that might induce him to think the archetype was brought hither by some who had been engaged in those expeditions, when they returned from the Holy Land."

After these remarks, no one will wonder at Dr. Milner complaining of the confusion and difficulty with which the study of Gothic architecture had been surrounded by the vague and unsettled manner in which terms had been employed by his predecessors and cotemporaries who had written upon the subject.

The employment of the term and its application seems to have arisen from an idea entertained by the Italians, that the style of building to which they applied it was introduced by the Goths after their incursion into Italy; this is evident from the expressions of Vasari, above quoted. Now, if the use of the title were restricted to those buildings with round arches which were prevalent after the fall of the Roman empire, there might be apparently some grounds for its assumption, but this does not seem to be the case even with the Italians, and certainly not with our own countrymen, although some of them doubtless thought that the Pointed arch was an invention of the Goths, in illustration of which we quote a passage on the subject from Sir Henry Wotton. He says:—"As for those arches which our artisans call of the third and fourth point, and the Tuscan writers *de tergo* and *de quarto acuto;* because they always concur in an acute angle, and do spring from a division of the diameter into three, four, or more parts at pleasure. I say, such as these, both for their natural imbecility of the sharp angles themselves, and likewise for their very uncomeliness, ought to be exiled from judicious eyes, and left to their first inventors the Goths or Lombards, amongst other reliques of that barbarous age.

Whether the Pointed style, or that previously existing, be considered as invented by the Goths, the notion in either case is false and without foundation. The Goths had no architecture of their own; and not only are they innocent of introducing any new style into Italy, but more than that, they do not seem to have caused any alteration in the old. What changes did take place arose very naturally from the gradual decline of art. It is not our intention in this place to enter into any discussion on the origin of Gothic Architecture; we defer that for a future paper on POINTED ARCHITECTURE; all we desire to state at present, is that neither the Pointed style nor that preceding, in which the semi-circular arch continued to be employed, were introduced by the Goths; and that, therefore, the term *Gothic* could not justly be applied to them on that score.

By many writers the term is doubtless used as a term of reproach, and is intended as equivalent to the words—uncivilized, barbarous; on which account, many persons of the present day have objected to its continued use. At the time of the revival of classical architecture, or rather of the adaptation of classic orders and details to modern architecture, the excellencies of Pointed architecture were but little understood or appreciated; and hence the desire to stigmatize it as barbarous. Since then, however, the prejudice for the orders has ceased, and Gothic art is viewed with a more favourable, and, we may add, more experienced eye, and men are desirous of rescuing it from any stigma, even though it be but a nominal one.

From this cause, many names have been suggested in lieu of the contemptuous *Gothic*, amongst which we may enumerate the following—*Christian*, *Catholic*, *English*, and *Pointed*—as being the most usual. It is true the word *Gothic* is ill-devised, insignificant, and entirely inapplicable, yet we cannot think that any of the terms proposed are sufficiently expressive to explode a title of so long standing and such universal acceptation. The term was originally, without doubt, employed as a mark of reproach, but now-a-days no such meaning is implied by it, and no one is misled by its use. In applying the term now, no one ever thinks of its original intention, but considers it solely as a phrase descriptive of a certain class of buildings, of which each man forms his opinion, quite independently of its appellation. Even supposing we were to explode this expression, what could be substituted in its place: no one term has been universally agreed upon; and we should have a general scramble, each partisan seeking to adopt his own peculiar title, and probably maintaining it to the utmost of his power; so that instead of one, we should have several titles, each striving for, but none obtaining universal adoption.

We submit, that it is better to have one term well established, even though it be confessedly a very incorrect one, than several exceptionable ones of only partial use.

Sir James Hall speaks to the point when he says: "In the present unsettled state of public opinion, both with respect to the origin and the history of this style, I have judged it best to attempt no innovation in this matter, and have made use of the name of *Gothic Architecture;* which, though certainly no less objectionable than many of those that have been offered to the public, has the advantage of being universally known and understood amongst us."

The two first names which we have mentioned as proposed substitutes for the word *Gothic*, namely, *Christian* and *Catholic*, are objectionable, on the grounds that this is not the only style which is entitled to such designations. Both Lombardic and Byzantine were styles adopted by the Christian church; nay more, in a certain sense they may be said to have been of Christian growth. Mr. Pugin contends, that although other styles have been employed in early ages, they

were rather of Pagan origin, or arose from unsuccessful imitations of Pagan buildings; in fact, that they were mere make-shifts, used only for a temporary purpose, until a more perfect system, and one more thoroughly Christian, should arise. We are most willing to admit that Gothic architecture is the perfection of Christian art, but, at the same time, cannot in justice allow its exclusive title to that term. The third term can only be of partial application, and only then correctly employed when applied to the style as practised in our own country: the theory that Gothic architecture originated in this country, has, we believe, been long since exploded. The term *Pointed*, though on many accounts a very correct one, is still open to similar objections to those urged against the two first, inasmuch as it would naturally include other styles besides the one to which it is intended to be applied.

In the quotations which we have above introduced from writers of the last two centuries, we have been necessitated to admit some contemptuous and opprobrious observations on the merits of Gothic buildings, when compared with those of Greece and Rome; but we cannot permit such remarks to pass by unheeded. At the period of what is called the revival of classic art, such unworthy opinions as those we have alluded to were far from uncommon; indeed, it was fashionable in those days to stigmatize everything belonging to the middle ages as dark and barbarous, and no one could give better proof of his admiration of classic antiquity than by reviling and sneering at every other kind of art, more especially at that which threatened a most dangerous rivalry. The quotations which we have already given on this head have been taken from Vasari, Wotton, Evelyn, and Wren; we will now give some more extracts of the same tendency, taken, for the most part, from the writings of the last-named architect. In his *Parentalia*, he says: "It was after the irruptions of swarms of those truculent people from the north, the Moors and Arabs from the south and east, overrunning the civilised world, that wherever they fixed themselves, they began to debauch this noble and useful art, when instead of those beautiful orders so majestical and proper for their stations, becoming variety, and other ornamental accessories, they set up those slender and misshapen pillars—or, rather bundles of staves and other incongruous props—to support incumbent weights and ponderous arched roofs, without entablature; and though not without great industry, not altogether naked of gaudy sculpture, trite and busy carvings; it is such as gluts the eye, rather than gratifies and pleases with any reasonable satisfaction. For proof of this, without travelling far abroad, I dare report myself to any man of judgment, and that has the least taste for order and magnificence, if, after he has looked a while upon King Henry VII.'s chapel at Westminster—gazed upon its sharp angles, jetties, narrow lights, lame statues, lace, and other out-work and crinkle-crankle, and shall then turn his eyes on the Banqueting House, built at Whitehall by Inigo Jones, after the ancient manner; or on what his majesty's surveyor has done at St. Paul's, and consider what a glorious object the cupola, porticoes, colonnades, and other parts present to the beholder; let him well consider and compare them judicially, without partiality and prejudice, and then pronounce which of the two manners strikes the understanding, as well as the eye, with more majestic and solemn greatness, though they, in so much plainer and more simple dress, conform to the respective orders and entablature, and, accordingly, determine to whom the preference is due. Not, as we have said, there is not something solid, and oddly artificial, too, after a sort; but the universal and unreasonable thickness of the walls, clumsy buttresses, towers, sharp-pointed arches, doors, and other apertures, without proportion; nonsensical insertions of various kinds of marbles impertinently placed; turrets and pinnacles, thick set with monkeys and chimeras, and abundance of busy-work and other incongruities, dissipate and break the angles of the sight, and so confound it that one cannot consider it with any steadiness where to begin or end; taking off that noble air and grandeur, bold and graceful manner, which the ancients had so well and judiciously established." "Nothing was thought magnificent that was not high beyond measure, with the flutter of arch-buttresses—so we call the sloping arches that poise the higher vaulting of the nave. The Romans always concealed their butments; whereas the Normans thought them ornamental. These, I have observed, are the first things that occasion the ruin of cathedrals; being so much exposed to the air and weather, the coping, which cannot defend them, first failing, and, if they give way, the vault must spread. Pinnacles are of no use, and of little ornament. The pride of a very high roof raised above a reasonable pitch is not for duration." Elsewhere speaking of their construction, he says: "Few stones were used but what a man might carry up a ladder on his back from scaffold to scaffold, though they had pulleys and spoked wheels upon occasion; but having rejected cornices, they had no need of great engines. Stone upon stone was easily piled up to great heights, therefore the pride of their work was in pinnacles and steeples." "The Gothic way carried all their mouldings perpendicular, so that they had nothing else to do but spire up all they could." "They affected steeples, though the Saracens themselves used cupolas."

We do not feel so much surprised at such expressions escaping men unattached to the profession, or even Vasari, for he was an Italian, and therefore naturally biassed in favour of classic art; but to hear such opinions from a man like Sir Christopher, must ever be a subject for wonder and regret. Wren was, without controversy, a man of great talents and high attainments; of considerable taste, and of unusual scientific knowledge; nor was he ignorant either of the nature of Gothic architecture—for he had made a special professional examination of its finest examples—or of its principles; for, as we believe, he learned much from them, and applied them in his own buildings. That prejudice should have extorted from such a man such unhappy tirades in condemnation of Mediæval art, is, we repeat, at once a matter for wonder and regret. It is pitiable to hear such a man challenging his predecessors with so great self-satisfaction, and inviting a comparison between his own works and theirs; complaining, too, of their faulty construction and useless ornaments, when he himself received no little scientific information at their hands; and as regards the useless ornaments—if, indeed, we do not give him too much credit for constructive skill—was not only aware of their practical utility, but even adopted their principle, though in a less skilful manner, in his own vaunted Cathedral. But we will not rest satisfied with our own authority. Since Wren's time, Mediæval art has met with less prejudiced judges; and many writers of high standing, and architects of well known ability, have given ample testimony in its favour. It is now more fully understood, and its beauties better appreciated; in short, Gothic art is now what Classic was in Wren's days—the "fashion." But ere we proceed to bring forward any more favourable witnesses, let us do Wren justice, and give another extract from his works, which tends in some measure to qualify his previous language.

Even he recognizes, in some few buildings of this style, "a discernment of no contemptible art, ingenuity, and geometrical skill, in their design and execution." Also—"Thus

the work required fewer materials, and the workmanship was, for the most part, performed by flat moulds, in which the wardens could easily instruct hundreds of artificers. It must be confessed, this was an ingenious compendium of work suited to these northern climates; and, I must also own, that works of the same height and magnificence in the Roman way, would be very much more expensive than in the other Gothic manner, managed with judgment."

But to pass on to later writers—Rev. J. Milner, alluding to Evelyn and Wren's remarks, says—"Every man who has an eye to see, and a soul to feel, on entering into York Minster and Chapter-House, or into King's College or Windsor Chapel, or into the cathedrals of Lincoln or Winchester, is irresistibly struck with mingled impressions of awe and pleasure which no other buildings are capable of producing; and however he may approve of the Grecian architecture for the purposes of civil and social life, yet he instinctively experiences in the former a frame of mind that fits him for prayer and contemplation, which all the boasted regularity and magnificence of Sir Christopher's and the nation's pride, I mean St. Paul's Cathedral, cannot communicate, at least, in the same degree."

Bishop Warburton says—"Our Gothic ancestors had juster and manlier notions of magnificence on Greek and Roman ideas, than those mimics of taste who profess to study only classic elegance; and because the thing does honour to the genius of those barbarians, I will endeavour to explain it."

Mr. Dallaway says—"Certain it is, that the Gothic churches, whatever be the peculiar manner of their era, present their beauties to every eye. We cannot contemplate them without discovering a majestic air well worthy of their destination, with a knowledge of what is profound in the science and practice of building, and a boldness of construction, of which classic antiquity furnishes no examples."

The following words of Coleridge are remarkable: in comparing the Classic and Gothic modes of architecture, he says, —"The Greek art is beautiful. When I enter a Greek church, my eye is charmed and my mind elated; I feel exalted, and proud that I am a man. But the Gothic art is sublime. On entering a cathedral, I am filled with devotion and with awe; I am lost to the actualities that surround me, and my whole being expands into the infinite; earth and air, nature and art, all sweep up into eternity, and the only sensible impression left is, that I am nothing."

Whewell, referring to the use of the word Gothic as a term of reproach, says—"If we would employ the term barbarous with any significance, it is not to be applied to one style of art merely because it differs from another. A Gothic building is no more barbarous than a Grecian one, if the ideas which govern its forms be fully understood and executed: but those attempts rather are to be called barbarous, which imitate the features of good models, and which, not catching the principle of the art, exhibit such parts incongruously composed and imperfectly developed. In writing Greek, an Anglicism is a barbarism; but we shall not be willing to allow English to be barbarous, because it is not Greek; and a mixture of the two is equally barbarous, whether it pretends to be one or the other."

Mr. Poole, a recent writer on the subject, is very warm in his admiration: he says—"But there arose in the west in the middle ages a style of architecture growing in all its parts and characters out of the wants of the church; and adapting itself to the expression of the very things which she desires to express in all her methods of embodying herself to the eyes of the world, and to the hearts of her sons. And so entirely did this style arise out of the strivings of the church to give a bodily form to her teaching, that it seems to have clothed her spirit, almost as if the invisible things had put forth their unseen, but powerful and plastic energies, and gathered around them on all sides the very forms and figures which might best serve to embody them to the eye of sense. A Gothic church in its perfection is an exposition of the distinctive doctrines of Christianity, clothed upon with a material form; and is, as Coleridge has more forcibly expressed, 'the petrifaction of our religion,' or, as it has been expressed by a mind essentially differing from Coleridge's, which makes the coincidence the more remarkable, 'the divine order and economy of the one seems to be emblematically set forth by the just, plain, and majestic architecture of the other; and as the one consists of a great variety of parts united in the same regular design according to the truest art and most exact proportion, so the other contains a decent subordination, various sacred institutions, sublime doctrines, and solid precepts of morality, digested into the same design, and with an admirable concurrence tending to one view,—the happiness and exaltation of human nature.'

"Much has been said about the proper designation of this style. The term Gothic has use on its side to so great a degree, that it will never be superseded, and though it has no truth in it at all, and was at first given in ignorant derision, one would scarce wish it altered; the style which it designates is exclusively Christian, and it is nothing new or displeasing to that which is distinctively Christian, to take a name from a scorner, and to convert the opprobrium into a glory.

"Such then is Gothic architecture:—theological, ecclesiastical, and mystical, in all its parts and characters. It grew to its perfection both in general design, and in more minute details of ornament and execution, during many successive generations; and although we have few churches entire and unmixed of its earliest forms, we have remains more or less perfect in almost every variation in its style, from the Norman of the twelfth century, to the elaborate perpendicular of the Tudor."

We conclude with the following remonstrance from Mr. Pugin, a gentleman to whom we are pre-eminently indebted for his perseverance in the study and defence of Mediæval art, and to whose "Contrasts," although somewhat overdrawn, we would beg to refer the reader, as apropos to the question before us.

Mr. Pugin says—"Before true taste and Christian feelings can be revived, all the present and popular ideas on the subject must be utterly changed. Men must learn, that the period hitherto called dark and ignorant, far excelled our age in wisdom, that art ceased when it is said to have been revived, that superstition was piety, and bigotry faith. The most celebrated names and characters must give place to others at present scarcely known, and the *famous edifices* of modern Europe sink into masses of deformity by the side of the neglected and mouldering piles of Catholic antiquity. If the renunciation of preconceived opinions on this subject, and the consequent loss of the present enjoyment derived from them, be considered as a great sacrifice, does not the new and glorious field that is opened offer far more than an equivalent? What delight, to trace a race of native artists hitherto unknown, in whose despised and neglected productions the most mystical feeling and chaste execution is to be found, and in whose beautiful compositions the originals of many of the most celebrated pictures of more modern schools are to be traced! what exquisite remains of the sculptor's skill lie buried under the green mounds that mark the site of once noble churches! what originality of conception and masterly execution do not the details of many rural and parochial churches exhibit! There is no need of visiting the distant

shores of Greece and Egypt, to make discoveries in art. England alone abounds in hidden and unknown antiquities, of surpassing interest."

Of the peculiar effect produced upon the mind by Gothic edifices, and of the principles upon which its excellencies depend, Milner gives us the following explanation :—"The eye is quickly satiated by any object, however great and magnificent, which it can take in all at once, as the mind is with what it can completely comprehend; but when the former, having wandered through the intricate and interminable length of a pointed vault in an ancient cathedral, discovers two parallel lines of equal length and richness with it; thence proceeding discovers the transepts, the side chapels, the choir, the sanctuary, and the ladye chapel, all equally interesting for their design and execution, and all of them calculated for different purposes; the eye, I say, in these circumstances is certainly much more entertained, and the mind more dilated and gratified, than can possibly be effected by any single view, even though our modern architects should succeed in their attempts to make one entire sweep of the contents of a cathedral, in order to show it all at a single view, and to make one vast empty room of the whole."

Mr. Poole adds—" But surely some part of the effect of a Gothic cathedral resides in that very excess of length over breadth, affording a long perspective, directing the eye towards the altar, through an avenue of oft-repeated similar parts, and creating, as it were, an artificial infinite. The roof as well as the walls of a Gothic building is so composed as to help this effect to the utmost. Groin beyond groin, boss beyond boss, pendant beyond pendant, is seen,—first of all each distinct and clear, but by degrees approaching and touching one another in the perspective, and at last, lost in the complexity—not confusion, but complexity—of the whole. The plain becomes obscure, the defined indefinite, in the long-drawn distance.

" Even irregularity of structure lends its aid to produce this effect, and irregularity is a beauty purely Gothic. The eye that wanders in an oblique direction, travels through the nearer arches to some unexpected aisle or chapel, and seems lost in an undefined distance. It is scarcely possible to exaggerate the effect of this combination of elevation, length, and irregularity, so averse from the Grecian concinnity and uniformity; especially when they are helped by the dim religious light poured through the painted windows.

" Fancy yourself for a moment standing just within the great western entrance of one of our cathedrals, and you will feel what is meant by breadth in architectural effect. The eye is of course directed eastward, and there it has its point of repose; and the great east window limits its view, at a distance, which, with all the accessories before mentioned, seems indefinite. But the aisles at either hand have absolutely no termination to the mind's eye. For a while you see through the intervening arches; but you see less and less at each interval, and long before the actual termination of the aisle, the piers, approaching one another in the perspective, close upon the unfinished view. The mind's eye goes forward, while the eye of sense is arrested. The limit is as effectual as if it had been abrupt; but it is so gradual that you scarce feel where it occurred. There is a perfect consciousness of the length beyond, notwithstanding the absolute impossibility of discerning it."

Thus much for the impugners and apologists of Gothic architecture ;—it will appear somewhat incredible that so great a difference of opinion should exist amongst men all eminent for taste and judgment, but such is the case; what in Wren's time was considered barbarous, is now upheld as scientific and beautiful. We follow the taste of our age, which we believe to be correct, and maintain the superiority of Gothic over Classical art, not only as regards its general effect, but also in scientific construction, correct and tasteful ornamentation, accommodation, and general convenience. In our previous extracts we have alluded more especially to the general effect of the two styles, we will now touch upon each of the other qualities seriatim, and, in doing so, we shall give, as before, greater prominence to the opinions of those who have arrived at a high standing in their profession, and principally of those who have devoted their time specially to this subject, than to any observations of our own; as we deem their authority will carry more weight with it than anything we can say. We need only mention the names of Pugin and Bartholomew, Willis, and Whewell, to obtain an attentive perusal, and would refer our readers for more extensive information on the subject than our space will allow of, to the standard works of those gentlemen.

In some of the extracts from the *Parentalia*, previously given, we hear Wren inveighing against the Mediæval builders on account of their rude and unskilful construction; we contrast their remarks with some others on the same subject by the late Mr. Bartholomew, than whom we could scarcely have a more impartial judge, for while on the one hand he is a great admirer of the Mediæval architects, he is no less predisposed in favour of Wren, on whose scientific skill in construction, he is continually pouring forth the most warm—we had almost said the most extravagant—encomiums. Let us hear what are his opinions in this controversy; they are expressed as follows :—

" During the middle ages, geometrical science was applied to architecture in the loveliest manner; the general plan, the columns, the arches, the doors, the windows, the galleries, the vaulting, the flying buttresses, every panel, every compartment, the most minute ornament, exhibited an intimate acquaintance with that profound and masterly science, without which building becomes vicious, cumbrous, expensive, mean, fragile, absurd and disgusting.

" After the decline of Gothic architecture, a foolish notion went abroad in the world, that cumbrousness and extravagance of material were characteristics of Gothic architecture; even that great and talented man, John Evelyn, who possessed a very superior knowledge of architecture, entertained the then current opinion: but of late, mankind have become strangely undeceived on this point; and the plans and sections of ancient and modern buildings, brought together in parallel, now fill the mind with astonishment, that so comparatively small a quantity of materials, and those frequently of minor quality, could have been piled up to exist, with little failure or decay, such a long course of time. It is not that Gothic buildings are always perfect in construction, but in general they are nearly so; in fact, so light are some of them, that they need more substance, as well as harder materials, to resist the mere operation of time upon their surfaces. The Gothic architects always built with the greatest economy: when square stone was easily procurable, they formed their walls very thin; but when, from the length of the carriage of it, it became costly, they used for their walls the most ordinary rubble-stone of the country, and they then gave to their walls thickness sufficient to prevent them from rending and rolling apart from the fluent nature of their materials."

Elsewhere he says—"Now the Mediæval Christian builders arrived to such a delicate and intimate acquaintance with architectural dynamics, that, by the discovery of the way in which all the particles of their materials are affected by gravity, they were enabled, by merely subjecting them to frangibility caused by compression, so to economize them and

reduce their quantity, that many members of Gothic edifices after five hundred years' devastation by time, are more sound than corresponding members of our modern buildings which have not subsisted fifty years, and which contain five times their proportion of materials.

"It was this scientific economy which enabled those real magicians to rear up securely their works so high towards heaven in the beauty of architectural holiness; it was this scientific economy which left them money enough to cover their sweet fabrics within and without with the richest intaglio, and the goldsmith's work of heaven, while their patrons grumbled not, nor grudged the rich profusion, but joined heart and soul in the goodly work, and the wise and noble fabricator needed none of that kind of over-persuasion, or cajolery, or intentional misunderstanding, or tasteful out-witting, by which alone the modern architect is frequently enabled to wring from his employer other than bare walls; this scientific economy rendered unnecessary the rabble of cement-makers and sand-concreters—those spendthrift empirics, which suck out the brains of architecture, rifle her pockets, violate her chastity, bruise her face to a mummy, and then cover it with oil-plasters and cosmetics of white-wash and iron oxide.

"So admirable in general is the skill displayed in the dynamic disposition of the material of a Gothic cathedral; so shrewdly are the forces of its gravitation reduced to simple compression, that the whole is like a wonderful piece of shoring, sublimely and permanently imitated in stone. He who compares its flying-buttresses to a piece of wood-scaffolding, at once confesses that it is raised with that art which emanates from the workman's most delicate and anxious caution."

In truth, the erections of this style are but the embodiments of constructive science, not only does the main form and general outline depend thereon, but even those peculiarities which an unpractised eye would be tempted to esteem mere decoration: but those who have made themselves acquainted with the subject, are well aware that the Mediæval architects never constructed decoration, but decorated construction; they made their building perfect, and then applied their ornament with most correct judgment and refined taste. A Gothic building is a practical illustration of the principle of the arch, and of its application in the most perfect form. We had almost termed it the extension and perfection of Roman architecture, for they were the first to apply the principle, but only in a partial and imperfect manner; the idea was new to them, and they did not fully comprehend it, they did not understand its universal applicability, and therefore only partially adopted it. In their buildings many of the forms of Grecian architecture still remained; they were fettered by its rules, by its influence, and thereby prevented from bringing their new theory to perfection. They had been used to the forms, they knew of no others, and hence arises their inconsistency. Roman architecture was, so to speak, a transition, and, so far, imperfect style; in it we see the new and old principles struggling for the mastery, yet each maintaining a certain influence; we have indeed the arch, but there still remains the entablature, which was in this place totally useless and inconsistent, they were each the exponent and characteristic of its own theory, and as the two systems were repugnant the one to the other, so was their introduction into the same building liable to the charge of inconsistency. The entablature in the one case answered the same purpose as the arch in the other, and therefore, where the one prevailed, the other should have disappeared; but this we know was not at first the case, it was left to the Mediæval architects to bring the new system to perfection. Roman architecture is but the germ, Gothic its complete development.

We cannot forbear offering one or two instances of the scientific skill of the Gothic architects, as exemplified in their mode of construction. It is a matter which has been frequently alluded to in other works, but one, we think, without which any treatise on Gothic architecture would be imperfect. It was their custom, as we all know, to cover their large buildings with vaults of masonry, a method of roofing in which they greatly excelled their predecessors. The Romans were acquainted with this method, and applied it in many instances, yet their specimens of vaulting, when compared with the Mediæval, appear but clumsy expedients; they were confined to the use of the common cylindrical and quadripatrite vaulting, or that of which each compartment consisted of four cells only, the latter kind being caused by the intersection of two cylindrical vaults at right angles to each other. But even in this simple kind of groining they found a difficulty, for when the intersecting vaults were of different span, and of the same elevation, their arches being confined to the semi-circular form, they were at a loss how to proceed. In Gothic architecture, the difficulty is entirely obviated by the employment of the Pointed arch, and by its application the Mediæval builders were enabled to construct vaults of so elaborate and varied a character, such as the Romans, with their forms, dared never to have dreamed of. But this is not the only improvement our ancestors effected in vaulting; the Roman vaulting consisted entirely of large stones, and was therefore of very great weight, a circumstance which was very detrimental to its application, for as the wall had to bear the entire burden, it was absolutely requisite that they should be of extraordinary strength. Now, our Gothic builders obviated this difficulty likewise in a most scientific manner; they made their vaults equally secure with a much smaller consumption of material, by which means they not only saved the walls an undue pressure, but also considerably reduced their expenditure throughout the building. This they managed in the following manner. In their large works, such as cathedrals, in which vaulting was more frequently applied, it was their custom to carry up a pier or bearing shaft on the face of the nave-shafts, either springing directly from the ground, or supported on a corbel at some point immediately above the piers. From the top of these shafts, as points of bearing, were extended ribs or arches across the nave from the bearing-shafts on the one side to those on the other, in three or more directions; in the more simple forms, each compartment of the vaulting consisted of six entire arches, enclosing four cells or spaces between the ribs, which were arranged in this manner;—from each of the four bearing-shafts sprang three arches; one, the longitudinal, extending to the next shaft on the same side of the nave, that is, in the direction of the length of the building; another, the transverse, stretching at right angles to the longitudinal to the shaft immediately opposite on the other side of the nave; and a third, the diagonal, extending between the most distant shafts from one angle of the bay to the opposite. These diagonal ribs intersect each other, and at the point of intersection butt against a key-stone, which generally extends below the level of the vault, and is sculptured in the form of foliage or some other ornament; this key-stone locks the system together securely. The ribs formed the constructive portion of the vault; they were the skeleton, as it were, on which the covering or cuticle was stretched: they were the only portions of the vault in which large stones were used, the cells being filled up with much smaller stones, and they of less ponderous material, by which means the whole vaulting was rendered lighter and more secure. In this way did they gain

an incalculable advantage over the Romans; nor did their skill cease here; having so far reduced the forces of the enemy, they prepared to carry the remaining thrust of the vault away from the walls of the clere-story, and conduct it safely to the foundations, and this they accomplished with equal or even greater skill. From that point of the clere-story wall, where the thrust of the vaulting was collected, the force was carried over the aisles by means of an arch termed a flying-buttress, which rested at its lower extremity on the pillar buttresses attached to the aisle-walls. But here it is necessary to notice one or two peculiarities which might be likely to escape the observation of a transient observer. Having collected the active force of the vaulting to one spot by means of the ribs, they there spread out the flying-buttress in the same manner as now-a-days we place a board against a wall in cases of temporary shoring, and sometimes placed one arch below another, the two being separated at the wall, but uniting ere they reach the wall-buttress, by which method the force was concentrated at that point, while the whole of the clere-story wall was equally supported. Having conducted the drift to this point, it remained to bring it safely to the ground; and how could this be effected? The method, which would at once naturally have suggested itself, would have been to extend the buttresses from the wall to such an extent as to receive the thrust within its mass until it reached the earth; but this would necessitate a very great projection, and therefore a large consumption of space and materials. This difficulty they met and nullified in the most skilful manner, and by a most simple contrivance. It was by merely superadding a pinnacle to the wall-buttress above the point at which the force was collected. We have now another force in operation, that of the downward pressure or gravity of the materials composing the pinnacle, and this combining with the thrust of the vault, changes the direction of that force so as to make it more nearly perpendicular, and bring it within a buttress of moderate projection, which, be it remembered, served a further purpose of strengthening the aisle-walls and diminishing their thickness, for it is well known, that a wall with buttresses at intervals, is as strong, or stronger, than a mere wall of the combined thickness of the wall and buttress. In this manner did they press everything, whether friendly or inimical, into their active service, and succeeded in rearing edifices of the most skilful construction, most rigid economy, and chaste and delicate decoration.

How Wren could have inveighed against the construction of our Gothic buildings we cannot understand, especially as he seems to have imitated them in several particulars, though not certainly with equal taste or skill. He has used very similar means to those above described, in resisting the thrust of his vaulting, in his vaulted Cathedral; buttresses are carried over the aisle to the outer wall, and are concealed by a screen running round the building, and having the appearance of an additional story, which certainly gives the building a more imposing appearance on the exterior, but at the expense of truth, and, like the dome, creates a feeling of disappointment when you enter the interior. To this circumstance Mr. Pugin alludes in a passage which we shall have occasion hereafter to quote. As regards Wren's objection respecting the size of the stones used in Gothic edifices, we need say nothing, it refutes itself, for surely if a building can be raised with equal security by the use of small stones which a man can carry on his back, it is much superior, at least in point of economy, to one raised with large blocks which require ponderous machinery to move them to their destined positions.

We leave Sir James Hall to answer objections made on the score of false proportions; he deals with them in a way no less summary than it is decisive. After speaking of the principles of Gothic architecture, he says:—"This view furnishes a complete answer to the common objection made to the Gothic style, of wanting proportions, for that accusation has always been the consequence of judging the Gothic by Grecian rules, in which case it could not fail to appear absurd and disproportioned; whereas when tried by its own laws, it will be found completely consistent and harmonious in all its parts;" of course, if persons commence by assuming Grecian proportions to be the acme of perfection, and all that differs from them to be false and barbarous, we may at once yield the argument, for the question is decided ere we commence.

Mr. Pugin alluding to the same subject says:—"Under the head of architectural propriety, we have also to consider the scale and proportions of buildings. Without vastness of dimensions it is impossible to produce a grand and imposing effect in architecture; still, unless these be regulated on true principles, they may destroy their effect by their very size; and here I wish to draw your attention to a point which will prove the great superiority of the Christian architecture of the middle ages, over that of classic antiquity, or of the revived pagan style. In Pointed architecture the different details of the edifice are multiplied with the increased scale of the building; in classic architecture they are only magnified." This principle of multiplying parts with the increased size of the building, is a characteristic of the style, and is one in our opinion in which it greatly excels its rival.

It now only remains to touch upon two subjects of comparison; the first as regards the application of ornament, and the last as to convenience and accommodation. The writers of Wren's time were too apt to consider Gothic architecture as a system of decoration, gaudy and puerile; a system in which useless ornament was the chief aim and object, and in which it was introduced without reason or moderation, and hence they termed it meretricious and barbarous. Investigation has taught us differently; and where they saw naught but confusion and redundancy, we detect order and sound judgment. Ornamentation was seldom introduced by our old church-architects without a cause or without a meaning: we do not mean to go so far as to assert that such was never the case, but we do say that there was, for the most part, a nice adaptation, a propriety, in their decoration; the parts to be enriched were not introduced without a specific object, and their manner of enrichment was made subservient to that object; for instance, look at the projecting string-course, the weather-mouldings of the heads of windows, to conduct the moisture from the enriched and delicate part of their work, so as to preserve it from injury, and the terminating dripstone to throw it off the walls. Each part was decorated so as at once to delight the eye, and answer an useful end; each moulding was beautiful and appropriate to its own peculiar duty; their contours varied, not from any wild fancy or exuberant imagination, but simply to make it efficient to the purpose for which it was employed. Look again at their buttresses, to which we have already alluded, and the gorgeous pinnacles, not a mere decoration, as our forefathers would have it, but a most useful and indispensable addition. But we can almost forgive them for seeing only the beauty, at least where they acknowledge so much, for the graceful finish given to the buttress thereby, is sufficient to justify such an addition, even supposing it served no other purpose than mere ornament, and we need not wonder at their resting satisfied with it as a means of decoration without looking to any further purpose. The buttresses themselves likewise were equally agreeable to the eye, as they were useful and essential to the construction; by them we

obtain a bold and pleasing variety in the main outline of the building, and that play of light and shade which adds so greatly to the appearance of a Gothic edifice. Looking once more at the smaller members, we find niches, corbels, bosses, vaulting ribs, each answering two ends, one useful, the other ornamental. What objects can be more beautiful than some of the Gothic niches, especially of the later styles, and yet what more necessary in a climate like ours; on the exterior of buildings, more especially, they serve to protect the higher branches of carving from the inclemency of the weather, and in the interior from accident or injury; but it was probably their unusual elegance rather than their usefulness, which caused their introduction as a means of internal decoration. In short, the Mediæval artists did not construct ornament, but ornamented construction. On this subject we add the following remarks from Pugin's Principles of Pointed Architecture:—

"The two great rules for design are these:—1st. That there should be no features about a building which are not necessary for convenience, construction, or propriety; 2nd. That all ornament should consist of enrichment of the essential construction of the building." "In pure architecture the smallest detail should have a meaning, or serve a purpose; and even the construction itself should vary with the material in which they are executed." "Strange as it may appear at first sight, it is in Pointed architecture alone that these great principles have been carried out; and I shall be able to illustrate them, from the vast cathedral to the simplest erection. Moreover, the architects of the middle ages were the first who turned the natural properties of the various materials to their full account, and made their mechanism a vehicle for their art."

Pointed architecture does not conceal her construction, but beautifies it: classic architecture seeks to conceal, instead of decorating it.

"The clumsy vaults of St. Paul's, London, mere coffered semi-arches without ribs or intersections, have their flying buttresses: but as this style of architecture does not admit of the great principle of decorating utility, these buttresses, instead of being made ornamental, are concealed by an enormous screen, going round the building: so that in fact one-half of the edifice is built to conceal the other. Miserable expedient! worthy only of the debased style in which it has been resorted to."

"An architect should exhibit his skill by turning the difficulties which occur in raising an elevation, from a convenient plan, into so many picturesque beauties; and this constitutes the great difference between the principles of Classic and Pointed domestic architecture. In the former he would be compelled to devise expedients to conceal these irregularities; in the latter he has only to beautify them But I am quite assured that all the irregularities that are so beautiful in ancient architecture, are the result of certain necessary difficulties, and were never purposely designed; for to make a building inconvenient for the sake of obtaining irregularity, would be scarcely less ridiculous, than preparing working-drawings for a new ruin. But all these inconsistencies have arisen from this great error;—the plans of buildings are designed to suit the elevation, instead of the elevation being made subservient to the plan."

The last observation of Mr. Pugin's leads us very naturally to the consideration of the next subject. The Greeks were confined to one plan in their edifices, the parallelogram; and in their application of this form they had but little choice, the main variation consisting in the arrangement of the external colonnade. It was a form well enough adapted to their religious observances, and restricted to buildings of that nature. Their edifices were chaste and grand, but chargeable at the same time with sameness and monotony; the one idea was universally resorted to, and probably because they had no occasion for any other. The Romans, however, did not restrict themselves to this form, their wants were more extensive than those of the Greeks, from whom they borrowed the main idea of their architecture; they wanted something more than temples; in short, they were a more secular people than the Greeks, and thought their secular buildings worthy of as costly magnificence as the temples of their gods. To this circumstance we owe the introduction of the practice of grouping, as it is termed, and the adaptation of the plans of the buildings to the various purposes of life; the Romans broke through the ancient rules of uniformity, and struck out into a wider and bolder path, which led by many directions to a great variety of results. But even the Romans were but tyros in this new system, which they left to after-ages to bring to perfection. The old Greek style was but little adapted to this altered state of things; and as much as the Romans gained in convenience, by so much they lost in appearance; the old principles could but ill brook their forced adaptation to new rules, and in process of time they died, (if we may be allowed the expression,) a natural death. The principles of Gothic architecture took their rise from the wants of the times, and gave completeness to that of which the Romans had originated the idea; and the style has this superiority over every previous one, that it can easily adapt itself to any purpose. No matter what shape you require your plan, nay, it matters not, though it be of no acknowledged or describable shape at all, you may rear upon it an elevation in accordance with the principles of the style, and one which only requires a skilful hand and practised eye to make it at once tasteful and convenient. Sir James Hall has the following trite remarks, which are very much to the point; he says:—

"In order therefore to apply Grecian architecture to our purposes, it has been found necessary very much to alter the old Greek plan; but this having but little variety, could not easily admit of any change. And a Grecian colonnade being of itself a most perfect form, we cannot well conceive how any thing should be taken from it or added to it without injury; at least, to do so would require a hand no less dexterous than that by which it was originally designed. It is not, therefore, wonderful, that our artists, employing Grecian architecture for new purposes, and introducing without ceremony forms unknown to the Greeks, should produce works devoid of those beauties for which theirs are so highly distinguished.

"The greatest detriment seems to have been occasioned by the introduction of windows, for which the old Greek masters had made no regular provision, but which are indispensable in most of our buildings. For by thus obtruding a new form upon the old style, its unity of design must be violated. The more so, that a set of windows partake, by their form and arrangement, of the regularity of a colonnade, and consequently occasion more disturbance of the general effect, than if there had been no resemblance between them.

"The necessity among the moderns of forming edifices spacious within, has been a source of great confusion; for the old Greek masters not having need of room, have left us no good examples of the kind, and our own artists, in pursuit of that object, have piled order upon order, and have joined together various parts in the same building, which, though each may be beautiful in itself, have no connection together, and can only deserve the name of more or less elegant pieces of patch-work.

Thus Grecian architecture, though rich in ornamental details, was susceptible of little variety in the general plan.

It has therefore failed when applied to our purposes, though in the hands of the old Greek masters, and employed in the construction of works suited to the wants of that people, it has far surpassed any other style. Gothic architecture, on the other hand, with great variety of ornamental details, admitting of the greatest latitude in the general plan and distribution of the parts, and being susceptible of almost any shape, is applicable to every purpose, and might be suited to the manners of every nation.

"A Gothic edifice receives and accommodates an immense multitude of people, and furnishes an unbounded supply of light in a manner which constitutes one of its principal ornaments. And this advantage seems to belong to the Gothic exclusively; for it does not appear, that in any other style of architecture, a provision has been made for the provision of light in an ornamental manner. It possesses, in the highest degree, several different and seemingly incompatible qualities. When entire in all its parts, everywhere clean and fresh, and enlightened by a bright sunshine, we admire its airy lightness and lively elegance; but when clothed in a majestic veil of obscurity, or reduced to ruins and overgrown with moss and ivy, we are struck with awe by its solemn grandeur.

"It results from this comparison, that the Grecian style excels in all those qualities of elegance and grace which depend upon the nice adjustment and masterly execution of details. Whereas the Gothic style, which with great truth has been compared to the genius of Shakspeare, is lively, picturesque, and sublime, qualities which are derived from the bold variety, and often from the wild irregularity, of its forms."

With this passage we naturally close our comparison; we have stated our own opinions on the subject, and produced authorities on both sides—the reader must form his own decision.

We now proceed to a description and arrangement of the style, but, before doing so, it will be needful to take some notice of those styles which immediately preceded it. Soon after the disruption of the Roman empire, we find architecture, lapsing into barbarism, still retaining strong characteristics of the previous style, but exhibiting only a clumsy imitation. The buildings of this age were but heaps of discordant parts, put together without reference to unity of design or arrangement. Out of this medley arose a style, which, however barbarous it may be deemed, can still boast some title to consistency, for, by this time, architects had broken through the trammels of the old methods which had hitherto fettered them. The style, known by some under the general title of Romanesque, and by others divided according to some marked peculiarity, or to the countries in which it was adopted, into Byzantine, Lombardic, and Norman, was the immediate precursor of the Gothic or Pointed style. It differs essentially from the Roman method in many respects, and presents us with several new principles, amongst which may be enumerated the entire disuse of the entablature, the arches springing directly from the capital of the pier or column; the total disregard of classic proportions, and an unusual variety and license in this respect, some columns being of the average height of the Classic orders, others much stunted, and others again exceedingly extended, more especially those attached to walls or piers, which become little better than vertical mouldings; the practice of including two or more arched openings under one common arch; and some few other particulars, which it is not necessary to mention. We give the following description of the buildings of the period to which we allude, as laid down by one of the writers already quoted. It will be seen to differ, in some respects, from our own account, but this may arise from his more especially alluding to some particular class of buildings, or because he was desirous of making a marked distinction between the erections of this style, and of that which followed it, the Gothic. He gives notice of some particulars which we have omitted.

"The arches," he says, "are round; one supported on pillars retaining traces of the Classical proportions; the pilasters, cornices, and entablatures have a correspondence and similarity with those of Classical architecture; there is a prevalence of rectangular faces and square-edged projections; the openings in walls are small, and subordinate to the surfaces in which they appear, the members of the architecture are massive and heavy; very limited in kind and repetition; the enrichments being introduced rather by sculpturing surfaces, than by multiplying and extending the component parts. There is in this style a predominance of horizontal lines, or at least no predominance and elongation of vertical ones. For instance, the pillars are not prolonged in corresponding mouldings along the arches; the walls have no prominent buttresses, and are generally terminated by a strong horizontal tablet or cornice."

The style, although an approach in that direction, differs in many material points from the later Gothic; but as we have occasion to notice the main features of distinction between the Roman and Gothic modes of building, and have also noticed the differences between the former and the Romanesque styles, we do not deem it necessary to institute a detailed comparison between the intermediate and Gothic systems.

Sir Christopher Wren takes notice of the variations of the two extreme styles, and although his deductions as to questions of merit cannot justly be assented to, his comparison as to principles is, for the most part, correct. He says:

"In this they essentially differed from the Roman way, who laid all their mouldings horizontally, which made the best perspective; the Gothic way, on the contrary, carried all their mouldings perpendicularly; so that the ground-work being settled, they had nothing else to do but to spire all up as they could. Thus they made their pillars a bundle of little tori, which they divided into more when they came to the roof, and these tori split into many small ones, and, traversing one another, gave occasion to the tracery work, as they call it. They used the sharp-headed arch, which would rise with little centering, required lighter key-stones and less butment, and yet would bear another row of doubled arches, rising from the key-stone, by the diversifying of which they erected eminent structures, such as the steeples of Vienna, Strasburg, and many others."

Mr. Rickman, to whom we are so much indebted for his researches on this subject, gives the following more detailed comparison in a tabular form:—

Grecian.	*English.*
The general running lines are horizontal	The general running lines are vertical.
Arches not necessary.	Arches a really fundamental principle, and no pure English building or ornament can be composed without them.
An entablature absolutely necessary, consisting always of two, and mostly of three, distinct parts, having a close relation to, and its character and ornaments determined by, the columns.	No such thing as an entablature composed of parts; and what is called a cornice bears no real relation to the shafts which may be in the same building.

Grecian.	*English.*
The columns can support nothing but an entablature, and no arch can spring directly from a column.	The shafts can only support an arched moulding, and in no case an horizontal line.
A flat column may be called a pilaster, which may be used as a column.	Nothing analogous to a pilaster; every flat ornamented projected surface is either a series of panels or a buttress.
The arch must spring from a horizontal line.	No horizontal line necessary, and never any but the small cap of a shaft.
Columns the supporters of the entablature.	Shaft bears nothing, and is only ornamental, and the round pier still a pier.
No projections like buttresses, and all projections stopped by horizontal lines.	Buttresses essential parts, and stop horizontal lines.
Arrangement of pediment fixed.	Pediment only an ornamented end-wall, and may be of almost any pitch.
Openings limited by the proportions of the column.	Openings almost unlimited.
Regularity of composition on each side of a centre necessary.	Regularity of composition seldom found, and variety of ornament universal.
Cannot form good steeples, because they must resemble unconnected buildings piled on each other.	From its vertical, lines may be carried to any practicable height, with almost increasing beauty.

Mr. Willis, in the annexed table, treats the subject in a somewhat different form, referring rather to rules of principles, than details of practice:—

Classical styles.	*Middle-Age styles.*
Different planes of decoration avoided, and never exceeding two in an entire composition.	Different planes of decoration placed behind each other to any number, and in every possible degree of variety, even in a single member, as in an arch.
Superincumbent weights united as far as possible, by resting on the horizontal cornice, which combines them into one mass.	Superincumbent weights divided into as many parts as possible, and then given to independent props.
Arch, foreign to this style, and when introduced its diagonal pressure excluded from the decoration.	Arch, the essential feature; its diagonal pressures studiously manifested, and the rest of the composition harmonized with them by other inclined lines.
Artifices of construction concealed, as impairing the simplicity of effect.	Every artifice of construction displayed.
Chamfered surfaces inadmissible, and mouldings can only stop against a surface perpendicular to their course.	Chamfered surfaces universal; mouldings are applied to them, and may die against them or any other surface at any angle.
Panels mere superficial ornaments.	Panels are apertures between the parts of the decorative frame of the building.

Elsewhere he adds:—

"These decorative features differ in many respects from the Classical, but the leading principle is to be found in the increased multiplicity of parts, and in a system which affected to support them all independently, arranging them in groups, in opposition to the Classical scheme, in which the parts are simple, and bound together by the dominant cornice."

"It is suggested to me by a friend," says the Rev. W. Whewell, author of Architectural Notes on German Churches, "that this distinctive principle of construction in the Gothic architecture, appears to be the admission of oblique pressures and inclined lines of support; in Greek architecture, the whole edifice consists of horizontal masses reposing on vertical props. In Gothic buildings, on the contrary, the pointed arch is always to be considered as formed by two sides, leaning against each other at the top, and pressing outward at their lower ends. The eye recognizes this statical condition in the leading lines of the edifice, and requires the details to conform to it. We have thus in the Grecian buildings nothing but rectangular forms and spaces, horizontal lines with vertical ones subordinate to them. The pediment is one mass with its horizontal cornice, and does not violate this rule. Arches, when they occur, are either subordinate parts, or mark the transition style, in which the integrity of the principle is no longer preserved. In Gothic works, on the other hand, the arch is an indispensable and governing feature; it has pillars to support its vertical, and buttresses to resist its lateral pressure; its summit may be carried upwards indefinitely, by the joint thrust of its two sides. All the parts agree in this character of infinite upward extension, with an inclination or flexure to allow of their meeting at top; and they obviously require, and depend on pressures acting obliquely."

He adds the following particulars in a more tangible and systematic form.

"1. The arch is essential, the entablature is not, and the columns support arches instead of entablatures.

"2. There are any number of planes of decoration one behind the other. When we have in this way several arches under one, we are led, as Mr. Willis has shown, to tracery; when we have arches of different forms one under another, we are led to foliation.

"3. The weights are divided into as many parts as possible, and these are given to independent props; whence we have, among other results, clustered piers and pillars.

"4. The diagonal pressures of the arch are displayed, whence we have buttresses and pinnacles.

"5. And, generally, the running and dominant lines are vertical in this style, as they were horizontal in the ancient styles: the characteristic forms of the one being horizontal, reposing, definite; of the other, vertical, aspiring, indefinite."

We do not feel it incumbent upon us to add anything to the above, the subject having been fully treated of by each

writer, the difference of treatment which may have been noticed, arising from the fact, that some of the writers have looked at the grand principles of the two styles, while the others have confined themselves to a comparison of the results of such principles, as applied in practice.

Having thus given a general description of the Gothic style, and its main characteristics, as distinguished from the Classical and succeeding modes of building, we will now proceed, in order to give a more detailed account of it as a distinct style, without any reference to other systems. In order to do this, it will be requisite to adopt some systematic arrangement in connecting and subdividing the various examples, so as to arrive at some clear notion of the rules which guided the Mediæval architects in the erection of their buildings; and in doing this we shall confine ourselves to the methods usually employed, not only because they are well established, but further, because they have been determined upon with great judgment.

Amongst the earlier writers, there does not seem to have been much attention given to this part of the subject; Warton, however, in his tract, attempts a classification, in which he thus distributes the different varieties:—In the first division, which he denominates *Gothic Saxon*, as not fully entitled to the name of Gothic, but having a decided tendency to that style, he places Salisbury Cathedral, and gives the thirteenth century as the epoch of that division. The next division, which he terms *Absolute Gothic*, he extends over the fourteenth and first half of the fifteenth century; he lays down as the characteristic feature, the ramification of the decoration in the window-heads, and gives as an example, the body of Winchester Cathedral. To the third division he gives a duration of only forty years, from A. D. 1441, to 1480, at which latter period he places the commencement of the *Florid Gothic*, the third division having the title of *Ornamental Gothic;* of the latter he gives King's College Chapel, as a specimen; and of the former, the chapels of St. George, Windsor, and of Henry VII., Westminster.

Mr. Dallaway arranges the styles as follows:—

	A. D.	During the reigns of
Semi or Mixed Norman..	1170—1220..	Henry II., Richard I., & John
Lancet-arch Gothic.....	1220—1300..	Henry III., & Edward I.
Transition or Pure Gothic	1300—1400..	Edward I., II., & III., & Richard II.
Decorated Gothic......	1400—1460..	Henry IV., V., & VI.
Tudor or Florid Gothic.	1460—1540..	Edward IV., to Henry VIII.

But the arrangement which most modern writers have followed, is that of Rickman, which is more simple, consisting of only three divisions, viz.:—

	A. D.
Early English	1189—1307
Decorated English	1307—1377
Perpendicular English	1377—1630

Mr. Bloxam subdivides the Early English into two distinct styles, and in this he agrees with Mr. Dallaway, but he names the earliest division Semi- or Mixed Norman, and the later Early English. He also subdivides the period allotted by Rickman to the Perpendicular style, restricting that title to those examples erected before A. D. 1540, and to the later buildings applying the term Debased.

Others again have retained the tripartite division of Rickman, but have used other titles, denominating the first division First Pointed, the second Middle Pointed, and the last Third Pointed.

The difficulty in classifying the examples of this style arises mainly from the gradual development of each particular division, the one merging into the other by such imperceptible degrees, that it is difficult to determine where the one commences and the other ends, although when each style is seen in its matured and perfect form, it is readily distinguishable from its neighbour. The most prominent characteristics of each style are to be seen in the windows, where the distinction is usually very manifest; the shape of the arches also, forms another principal feature by which the date of a building may be to a certain degree determined, although not very accurately, for the same shaped arches are used in different styles. Perhaps the most certain distinctive marks are to be observed in the mouldings and matters of detail; and these, taken together with the more prominent features, will in general lead to a tolerably accurate decision. We shall consider the peculiarities of each style in a systematic and detailed form, dividing a building into its several component parts, and comparing them, as it were, analytically. Before entering on this task, however, we deem it advisable to refer to the nomenclature and system of classification in the description of particular buildings, recommended by Mr. Willis; so that should any of his terms occur in the following pages, they may be correctly understood. We must recommend them for adoption, as affording, for the most part, a simple, intelligible, and systematic mode of arrangement.

In the description of a building, he advises that one bay of the interior should be taken as an example; divided into its several parts, and each of these treated fully and systematically. This, with a specification of the number of bays, will form a description, generally speaking, of the main portion of the building, unless any differences occur in the other bays, and in such case it will be requisite of course to note the variation. The same course is to be pursued on the exterior of the building, but here it will be requisite to note, in a more especial manner, the arrangement and decoration of the principal façades, as also of the towers and spires, if there be any, and of any other similar addition.

The following are some of the principal terms employed by him in his nomenclature.

Impost, the line or surface of common section between the arch and the support upon which it rests; not, as heretofore explained, the mouldings or capital from which the arch springs, but the plane upon which the arch and pier meet.

Continuous imposts, those in which the mouldings of the arch are continued, without interruption, to the ground.

Discontinuous imposts, where the mouldings of the arch die into the pier without any band of mouldings.

Corbelled imposts, where the mouldings of the arch spring from a corbel without being continued to the ground.

Arches he divides into *simple* and *compound*, the latter term being applied to such as consist of several different surfaces projecting one beyond another, or such as may be resolved into a number of concentric archways successively placed within and behind each other.

Shafted archways are those in which the horizontal section of the shaft differs from that of the arch.

Banded archways, those in which the horizontal sections of the pier and those of the arch coincide, but which have impost mouldings or capitals.

Shafts are divided as follows:—

Vaulting shafts, those which sustain the ribs of vaulting.

Bearing shafts, those which sustain the whole superincumbent weight.

Sub shafts, such as sustain arches of which the upper side is united to the soffit of the next arch or wall.

Face shafts, such as sustain arches of which the back only is united to the wall, and which appear as though placed upon the face of the wall.

Edge shafts, those which support arches united by their

sides and back to the nearest wall or arch, so as to appear to support the edge only.

Nook shafts, are similar in plan to edge shafts, but the rib differs from an edge-rib in not being united to the contiguous wall, but, like the shaft, nestled into the re-entering angle formed by the side and face of the contiguous arches.

The same terms are applied to the arches which are sustained respectively by the above-named piers; thus we have *sub-arches*, *face arches*, &c. Shafts which sustain vaulting ribs are termed by Mr. Whewell *Building pillars;* and compound piers, *pilaster masses.*

When an arch is indented with foils or cusps, it is said to be *foiled*, but when it has another foiled arch below the simple one, it is said to be *foliated.*

Thus, in describing an archway, it is first designated as simple or compound, and, if compound, it is described as consisting of so many orders, according to the number of arches it consists of, or, in other words, according to the number of the different soffits or projections, and thereupon each order is described separately in reference to the nature of the impost, whether continuous or discontinuous, as to the position of the shafts and arches, as sub-shafts, face shafts, &c., and so on, in accordance with the nomenclature above given.

Mr. Whewell describes the arches of a vault as *longitudinal*, *transverse*, and *diagonal*, the first term being applied to those running in the direction of the length of the building; the second, those carried at right angles to the longitudinal; and the last, to those carried diagonally, intersecting each other at the centre, and connecting the extreme angles of the severy.

Vaulting is also described as *quadripartite*, *sexpartite*, *octopartite*, &c., according to the number of cells contained in each bay.

Mr. Willis divides the intersections of vaults into *groins* and *ridges*, the former term being applied to those forming an external angle or *edge*, and the latter to those forming an internal angle or *nook*. Hence we have *groin ribs*, *ridge ribs*, and *surface ribs*, the last expression applying to those spread over the surfaces of the vaulting cells.

It will be further necessary ere proceeding to the particular description of the styles, to give some account of the various kinds of arches employed in Gothic buildings. This is especially necessary, as the arch forms a very strong characteristic of the style, and is of very great assistance in deciding, by its shape and formation, the period to which any particular example may belong.

The arches in use in Mediæval buildings, are the triangular, circular, and pointed. Of these, the first, composed of two straight lines inclined towards each other, and forming two sides of a triangle, are almost peculiar to the Saxon style, but are occasionally, though rarely, found at a later period; the second, the outline of which consists of a curve of constant curvature, or some portion of a circle, may be divided into three different kinds, according to the proportion of the circle which it includes.

The most simple of these three kinds, and that which is the more frequently used, is the semi-circular, comprising one half of the circle, the centre of which is in the springing line of the arch. This form was in general use from the time of its introduction by the Romans, until the establishment of the Gothic style, from which it was almost discarded; some few instances are, however, still to be found, in examples posterior to that period.

The horse-shoe arch, as it is called, containing a larger portion than the half of the circumference, and having the centre of the circle above the spring-line, is of very rare occurrence at any period. The segmental, on the contrary, which contains a portion of a circle only, and which springs above its centre, is of occasional employment at every period, more especially as an arch of construction, but also in apertures, as doors and windows. There is yet another method of using the semi-circular arch, by stilting it on uprights, so that the curve of the arch is continued downwards in a straight line below the springing of the course; this is found more especially in the pre-Gothic styles.

Of the Pointed arch, which is characteristic of the style, there are many varieties. In the first place, they divide themselves into two-centred and four-centred arches, of the former of which there are at least three descriptions; the Lancet, the Equilateral, and the Obtuse.

The Lancet consists of two segments, the centres of which fall outside the arch, the radius being of greater length than the span: it may be described about an acute-angled triangle. The equilateral has the centres of the segments on the opposite extremities of the span, the radii of the circles therefore being equal to the span of the arch; it may be described about an equilateral triangle. In the obtuse arch, the centres of the segments fall within the arch, and has therefore the radii less than the span of the arch; it may be described about an obtuse-angled triangle.

The four-centred arch, which is also named the Tudor arch, from the dynasty during which it was in use, is described from two centres on either side, the one being on a level with the springing, and the other at a considerable distance below it, the curves of lesser curvature, or those described with the longer radius, meeting at a point, and thus leaving the arch still pointed.

There is another kind of arch termed the ogee, each side of which consists of a curve of double curvature, the lower curve being concave on its under side, and having its centre on a level with the spring, and the upper convex, with the centre on a level with the apex.

There yet remains to be noticed a more ornamental kind of arch, which is by no means uncommon, and is what is termed a foiled—or, to designate it still more closely—a trefoiled arch. The appellation arises from the shape or outline, which is that of a trefoil, or rather of a semi-quatrefoil. There are two kinds of these; the round-headed trefoil, in which the curve between the cusps is a semi-circle, and the pointed trefoil, in which the same curve is composed of segments less than a semi-circle. There are also what are termed square-headed trefoil arches, in which the centre compartment, instead of being circular, is square or rectangular, leaving the side-ones still circular.

Such are the arches most frequently applied in Gothic buildings; there are some few other varieties, but they are of so rare occurrence, that it is scarcely worth while taking notice of them.

But to return to the classification and description of the various styles; the first of which, the Early English, dates from A. D. 1180 to 1300, including the reigns of Henry II., Richard I., John, Henry III., and Edward I., may be called, in general terms, the style of the thirteenth century. The architecture of this period is exceedingly beautiful and chaste, simple and elegant in design, and excellent and delicate in execution, equally applicable to the modest village church, and the noble abbey or cathedral, remarkable in the one for its unobtrusive simplicity, and, in the other, for its solemn and majestic grandeur.

In describing this and the succeeding styles, we shall follow the method commenced by Rickman, and adopted by most of the later writers, of considering them in detail; that is to say, we shall select the most important of the component

parts of a building, and describe them separately as to their character and treatment in each style. We shall arrange these parts and their descriptions in the following manner: *Arches*; next their supports, *Piers*, which we subdivide into *Shaft Capital*, and ***Base***; then *Windows*, *Doorways*, *Buttresses*, *Parapets*, *Roofs*, and so forth, including *Towers*, *Spires*, and decorative features, such as *mouldings*, *pateræ*, *foliage*, and other sculpture.

Arches. The arches principally in vogue at this period, were acutely pointed, either lancet or equilateral, the former being most prevalent in the larger structures; in which, however, the latter was not unfrequent, as may be seen at Salisbury cathedral, where it is more frequent than any other shape. It is, however, a rule that the arches are comparatively more acutely pointed in larger churches and cathedrals, and accordingly we find the obtuse-pointed arch most extensively used in small parish churches. The semi-circular arch was not entirely out of use at this period, as we find it frequently combined with the pointed, two or more of which are sometimes included under one of the former shape, as at Whitby Abbey, and in other examples. There are also not a few instances in which the semi-circular form is used alone, and sometimes treated in a similar manner as regards decoration, to those of a later date. Segmental arches were likewise in use, not only as constructive arches, but also as coverings for apertures, and more especially doorways.

The soffits of the arches were, in the more magnificent examples, richly moulded with a series of projecting rolls with deep hollows intervening, but in smaller churches they were for the most part merely cut in recession, so as to present two or more surfaces, having the angles of each projection plainly and broadly chamfered.

Piers. In large edifices the *shafts* of the piers were often composed of a series of pillars clustered together in various forms, to the number of four and upwards. Sometimes these shafts were attached to each other, but they were frequently detached, consisting of a massive central pier, usually circular, but sometimes octagonal or square, and surrounded by four or more slender pillars, entirely detached from each other and the central shaft, except at the base and capital, and occasionally at one or two points in the height of the shaft, where they were connected by narrow bands or annulets of moulding. These annulets are used also in the other kinds of shafts, and are characteristic of the style. The smaller pillars, when detached, are often constructed of a more costly material than the other parts of the shaft, being sometimes of Purbeck marble and polished. The same arrangement of central shaft, with four surrounding pillars, is to be found with the pillars attached to the main pier; specimens of both kind exist at Westminster Abbey. The pillars are usually simple rounds, but sometimes they have a narrow vertical fillet.

In smaller churches the shafts were a simple circle or octagon in plan; more frequently the former, and are distinguishable from those of a later date only by the details of base and capital. It frequently happens that the shafts of piers in the same edifice differ in form, and they are frequently so arranged as to have circular and octagonal forms alternately in the same arcade.

The *capitals* of this period are usually bell-shaped, and are often, especially in the smaller examples, quite plain, with the exception of a necking, and one or two mouldings beneath the abacus. In such cases, they are distinguished from the capitals of later styles only by their mouldings, which consist of rounds and deep hollows; the bell is generally very deeply undercut, which is a strong characteristic of the style. The mouldings are generally plain and few, but sometimes the nail-head or dog-tooth ornament is inserted between them. In the larger and richer specimens, the bell is covered with foliage, which springing from the necking, is curled over with a graceful curve beneath the upper mouldings. The foliage is somewhat stiff in appearance, but of a bold and striking character, and is sometimes undercut to such an extent as to be partially detached from the bell; it consists for the most part of a variety of adaptations of the trefoil leaf, and we rarely meet figures of any kind. In clustered piers, the capitals follow the form of the pier; as also in the single shaft they adopt the same form, with the exception that the multangular shaft has not unfrequently a circular capital. The abacus is either circular or octagonal, and sometimes square in plan, and consists of mouldings varying in number, and made up of deep hollows with overhanging rounds, which are either plain or filleted.

The base consists of a series of mouldings, frequently of a deep hollow and fillet between two rounds, of which the lower one projects beyond the other; it is also often similar to the Attic base, with the exception that the proportions differ, the upper torus being greatly reduced, and the concave mouldings deeply undercut. The base most frequently stands upon a single or double plinth, which in the earlier examples is square, having the angle covered with a leaf which springs from the mouldings of the base, and falls over the plinth. In later specimens, the plinth assumes the form of the base, and is either circular or polygonal; it is sometimes of great height, having a second series of mouldings below the base.

The *windows* of this style are for the most part long and narrow, with acutely-pointed heads. The earliest and simplest form is that of a long narrow single light, with arched head, and without moulding of any kind either internally or externally, the exterior angle being merely chamfered, and the interior widely splayed. Such windows were sometimes without any weather-moulding, but occasionally a string-course was carried from one window to another, at a level with the springing of the head, and then lifted over it, adopting its form, and carried on to the next aperture. In later times such windows appear in groups of two, three, or more, the first being commonly found in the side-walls of churches, and the latter being almost confined to the east end, except in very large buildings, where it is found in all positions. The separate lights of these groups are generally placed at some distance apart on the exterior, so as scarcely to appear as belonging to the same window; but in the interior, owing to the great splay given to each light, the distance between them appears inconsiderable, giving them the appearance of a single compound window. This idea is sometimes manifested on the outside by the two or more lights being contained under one drip-stone. The glass is inserted near the outer face of the wall, which circumstance, taken in connection with the great thickness of the walls, accounts for the difference of the size of the aperture on the two faces of the wall. This arrangement was in all probability adopted for the purpose of obtaining a larger proportion of light, or rather spreading what they obtained over a larger portion of the interior.

The arches of the splay on the interior, seldom follow the form of the window heads on the exterior, but spring from a lower level, and are almost always chamfered or moulded at their angles or edges; the mouldings projecting below the soffit, and either dying into the jamb, or resting upon corbels at the spring of the arch.

In windows of three lights, the centre one is almost always of a greater length than those at the side, its head rising considerably above theirs, so as to preserve the arched form in the entire window. We occasionally meet with

windows of four lights, the two centre ones rising above the others, but more frequently with others of five or seven lights rising in gradation to the centre one, which is higher than the rest. These large windows have a very beautiful effect, occupying as they do nearly the whole of the east wall. In all the above cases the jambs are sometimes plain, being merely chamfered and splayed as before described; but at other times we find them decorated with small detached pillars, with moulded arches. This is most frequent in the interior, where the shafts are not unusually of polished marble, but such decoration is also to be met with on the exterior, especially in large buildings. In windows of a late date, the arched heads are sometimes foiled.

Before the termination of this style, windows of a somewhat different appearance were introduced, which originated thus:—In cases where windows of more than one light were employed, it was, as has been mentioned, a not unusual practice to include them under one arch, the head of which was left plain; but in the course of time this space began to be pierced with another small light in the form of a circle or trefoil, which at once relieved the blank space beneath the arch, and admitted a greater amount of light. At Brownsover church, Warwickshire, there is a very simple arrangement of this kind, in which the third light is somewhat in the shape of a diamond placed between the arched heads of the principal lights, to which two sides of the figure are parallel, the two remaining sides being parallel to the curved sides of the larger connecting arch. In the earlier specimens of this class, the openings are still chamfered only, with shafts sometimes on the inside; but at a later period the lights were brought closer together, and were divided by slender shafts, and the arches and ornamental lights in the head moulded and foliated. We have many beautiful examples of windows of three lights, with three foliated circles in the head, and sometimes of five or more lights similarly decorated. The windows of the Chapter-house, York, are most beautiful specimens of five lights, which are arranged in two pairs of two lights each, connected under one arched head containing a foliated circle: the central light being also surmounted by an arch containing a trefoil. The whole of these are enclosed under the principal arch, which contains above the lights, three large foliated circles. The effect of this design is grand in the extreme. The east window of Lincoln Cathedral is another magnificent example: it contains eight lights in all, which are divided into two compartments containing four lights each, with arched heads filled with foliated circles, whilst the principal head is filled with one large circle containing seven of a smaller size. This is probably the largest window of the kind we possess.

Circular or rose-windows are not unfrequent in this style, and are divided into compartments by slender shafts with capitals, &c., radiating from the centre, and sustaining at the circumference small arches, which are usually trefoiled. Smaller windows of this form are either left plain, foiled, or filled with quatrefoils, &c. Windows of triangular shape are also found, as well as a peculiar sort of window in the form of what is called the Vesica Piscis; but these are always small, and placed in subordinate situations, such as the gables or the clere-stories of parish churches. Small square-headed windows are sometimes employed, but only in towers and similar situations.

The *dripstones* follow the form of the arch, and usually terminate on a projecting head or knob of foliage, but are sometimes returned horizontally along the wall; the moulding has a deep hollow on the under side to prevent the rain running over it. A string-course is generally carried along the external and internal walls, immediately below the windows.

The *doorways* of this period are most frequently furnished with nook-shafts in the jambs, which are, for the most part, detached from the walls, except at the capitals and bases. The more simple doorways have only one shaft on either side, supporting an archivolt of a few bold mouldings, the whole surmounted by a simple hood-moulding conforming to the shape of an arch, and terminating in a head or bunch of foliage, or returned in a horizontal direction along the walls. More elaborate specimens have two or more shafts on either side, and a greater number of mouldings in the arch. The jamb is cut in recession to receive the shafts, and the spaces between the mouldings or shafts are frequently filled up with the dog-tooth ornament or a running pattern of foliage. The arched heads of doorways are most frequently pointed, but not rarely round-pointed or square-headed trefoil.

The doorways of the larger structures are mostly divided into two arched apertures by a simple or clustered shaft, which is often of polished marble, and furnished with a richly moulded or foliaged capital. The arches are also foiled or foliated, and enclosed under one main arch, the space between being perforated in circles, trefoils, &c., and sometimes filled with groups of sculpture.

The *doors* are either plain or covered with iron scroll-work, sometimes proceeding from the hinges, which are often of a very ornamental character, but at other times nearly plain. In some cases this scroll-work is very elegant, and completely covers the door.

The *buttresses* of this period are, for the most part, of a simple character, consisting, in smaller churches, of two or more stages, the lowermost projecting beyond the other, each set-off being sloped at the top so as to carry off the rain. The buttress finishes at the top under the parapet, or eaves, with a simple slope similar to that of the other projections. In larger buildings, the buttress is frequently finished with a triangular head or gablet, but is seldom carried above the parapet, except where stone vaulting is employed, and, in such cases, it is covered with a pinnacle which is either plain or enriched with blank arcades. Sometimes each set-off is finished with a triangular head, and, at others, the water-table is continued round three sides of the buttress. The edges of such buttresses are often chamfered, or the angles ornamented with slender shafts; occasionally, too, the face is formed into a niche to contain a statue.

There is a peculiarity about the position of buttresses of this period, which is often the only means of distinguishing them from those of later date; at the angles of buildings they are not placed diagonally, but at right angles to the wall, so that whereas in this style we require two buttresses at each angle, placed at right angles to each other and to the adjoining walls, in the following styles we need but one.

Flying-buttresses, which are arches springing from the wall-buttresses over the roof to the clere-story, were now first introduced, and are common in all large buildings with vaulted roofs. They are of simple design, with a plain capping and archivolt.

Parapets are not frequent in small buildings, the roof being carried over the walls with dripping eaves; but when they occur, they are of a simple character, finished at the top with a moulded capping, and supported underneath by a corbel-table, which consists of a series of blocks moulded or sculptured in the form of heads or masks, and sometimes of foliage; these are often connected together by trefoiled, or other arches. The projection of the parapet above the corbel-table is often merely chamfered, but in the richer specimens moulded, and sometimes decorated with the dog tooth ornament. In cathedrals, we occasionally see the

parapet relieved by panelling, as at Salisbury, where the panels are of the form of trefoiled arches, and sometimes pierced with trefoils, &c. Battlements are not often found in this style.

Pinnacles, which rise above the general level of the buildings, are often mere continuations of the rectangular buttress capped with simple pyramids of square or polygonal bases, without any ornamentation, but in more costly examples the latter form is chiefly employed for the entire pinnacle, and is enriched with one or more series of blank arcades, which give them a light and elegant appearance; in some instances, the arcades are perforated.

The *Roofs* are of a high pitch, the angle at the apex coinciding mostly with that of an equialateral triangle, but sometimes they are more depressed. In small buildings, as we have above stated, they not unfrequently overhang the walls, but in larger ones they are stopped by the parapet. In the interior of large churches and cathedrals the roof is generally vaulted, the vaulting being of the simplest kind, or that which has been described as quadripartite, that is, consisting of four cells in each bay, and being divided only by transverse and diagonal ribs, not having a longitudinal one along the apex, as in later examples. The mouldings of the ribs consist generally of rounds plain or filleted, and deep hollows, and are covered at their intersection by bosses of sculptured foliage.

The wooden roofs of the period were like all Gothic roofs, except those of a very late date, open to the ridge, and unceiled, so as to afford a view of the timbers from the body of the building. In recent times, however, most of these open roofs have been excluded from view by the intervention of a modern ceiling, and it is seldom they are brought to light, except on the occasion of an extensive repair or restoration of the entire fabric. This fact will account for the paucity of information respecting this portion of a building, a want which is more particularly felt in respect of the early styles; so much so, indeed, that we scarcely know for certainty how to distinguish the early English from the Decorated examples, and it is probable that there is no very marked difference between them, although it is usual to make a distinction in treatises of this nature.

The most simple roofs, which we may attribute as more particularly belonging to this period, consist only of common rafters placed at short distances apart, without the intervention of trussed principles, and have a very good effect, owing to the lengthened perspective produced by the frequent repetition of the same parts. The rafters are very often secured by means of collar beams and braces, or by intersecting braces springing from purlins about half-way up the rafters, and rising to a higher purlin on the opposite side of the roof. These two systems are very common and simple, but not unfrequently the two were united, so as to have a collar beam with cross braces intersecting a point usually above it; and sometimes, in addition to these, we have a strut below, all resting upon the wall-plate, so that the entire outline of the under side presents the appearance of a polygonal arch. In some instances, the braces are curved in the form of a pointed arch. Where the roof is carried over both nave and aisles, the portion over the nave is of a similar description to those above mentioned, and in that over the aisles, the side next the nave is supported by short beams or struts abutting against the nave walls; this is also common in lean-to roofs. Although the practice of adopting only common rafters may be more usual, the introduction of principals is not unfrequently resorted to, which, in such instances, follow the same constructive form as the common rafters before referred to, the common rafters, however, are of a more simple character than the principals.

Tie-beams do not seem to have been of frequent occurrence, and king-posts are still less usual, their absence being very readily accounted for by their necessary weight in roofs of a high pitch; when tie-beams are employed, they are sometimes supported underneath by sloping braces abutting against the wall, and this method removes, in a great degree, the objection made against ties, of destroying the vertical tendency of the general design.

The timbers of the roof are often plain or chamfered on the edges, but in the richer specimens they are moulded, or at least the main beams, such as principals, purlins, wall plates, and such like, but the common rafters are mostly plain.

The *Towers* of the period are of various proportions, but generally bear a substantial, massive appearance; they are almost always square on plan, but sometimes octagonal, and in a few instances square below and octagonal above. They are strengthened at the angles by buttresses, two at each corner, projecting at right angles to the walls, which generally terminate a stage or more below the top; projecting stair-turrets are not uncommon, but are sometimes concealed by the buttresses.

The tower is divided into stages by set-offs or otherwise, of which the upper ones are frequently decorated with blank arcades, a few being perforated, to serve as windows; sometimes the faces are perfectly plain, with the exception of the apertures for windows, which consist of one or more light, the most important being placed in the upper stories. Here, in smaller churches, we generally have a window of two lights divided by a shaft, and having a foiled aperture under the arched head, but in larger churches we find windows of three lights, or triplets, but of equal height; in the lower stories we usually find single lancets.

These towers are occasionally covered by a low pyramidal or a gable roof, but more frequently by a lofty spire of stone or wood, although for the most part less acutely pointed than those of a later style. The spires are almost invariably broach-spires, that is to say, such as spring directly from the roof, without the intervention of a parapet; their plan is almost always octagonal, four of the sides sloping down to the eaves, but the four corner ones leaving a triangular space at each angle of the tower uncovered, which is occupied either by a pinnacle, or more frequently by a triangular pyramid, which connects the angles of the tower with the angular faces of the spire. Towards the lower part of the spire, the cardinal sides are furnished with windows, which rise perpendicularly, so as to give a projection at the top which is covered with a gable-head, and sometimes we have two or more tiers of such windows placed often on alternate sides of the spire. The whole is surmounted by a finial and vane. The cornice below the eaves is frequently ornamented with the dog-tooth moulding, or a running pattern, and is often supported upon a bold corbel-table.

A very elegant substitute for tower and spire, is employed in small churches, in the shape of a bell-gable, with one or more openings to contain the bells.

The *Mouldings* of the style have no great variety of form, but consist almost universally of bold rounds with deep undercut hollows intervening, so as to produce a great amount of shadow. The rounds are sometimes filleted with one or more fillets, but this is not usually the case with the smaller mouldings. Where several mouldings are connected together, there is considerable difference of size, the entire series being generally divided into a few distinct portions by mouldings of a large size, which are often filleted, and the intermediate spaces filled up by smaller plain mouldings. In such cases, it will be generally found that the mouldings are so arranged,

that if a line be drawn to touch the most prominent points, it will form a succession of rectangular recesses. The large rounds are sometimes brought to a pointed edge in the middle, and the smaller ones very deeply undercut on one side: in some cases, a fillet intervenes at the junction of the round and hollows, but they mostly unite in a continuous line without any interruption. String-courses often consist of a plain round-moulding, or of a roll-moulding of two different curves, so as to cause the upper half to overlap the lower; sometimes they are mere slopes with hollow underneath. Hood-mouldings consist for the most part of an overlapping round with deep hollow underneath. The base-mouldings are composed of a series of slopes, with sometimes a string-course moulding along the top, but in more elaborate works they comprise a series of mouldings consisting of projecting and overhanging rounds deeply undercut.

The hollows of the mouldings are often filled with ornaments peculiar to the style, of which the most usual and characteristic is that termed the *dog-tooth* ornament. It is a kind of pyramidal flower of four leaves, the division between the leaves being placed in the centre of each side of the pyramid; the flower is placed in an inverted position, the base of the pyramid being placed against the hollow, with the apex projecting. This ornament varies to some extent in different examples, but always preserves the same general appearance; it is very effective on account of the deep shadow produced at the division of the leaves. They are placed in a hollow moulding, or in the edge of a jamb, either singly, with a space intervening between each two, but more frequently in close proximity to each other. Single leaves and flowers of a different character are sometimes inserted in a similar way, and sometimes a running pattern of leaves or foliage.

Sculptured foliage is much used in the more costly buildings, forming capitals, corbels, crockets, and bosses, and is usually of a stiff character, that is to say, the leaves have a crisp appearance not observable in other styles. It is very beautiful, however, and worked with much taste and freedom; although it does not present an appearance so natural or flowing as that employed during the next period. Amongst other varieties of foliage, the trefoil is predominant, the two lower lobes of which, and sometimes all three, are worked with a bulb or swelling in the centre, the middle lobe being frequently of larger size than the others.

The crockets likewise are usually in the form of a trefoil-leaf, curled back like the head of a pastoral staff.

The *walls* of large buildings are frequently ornamented by a series of blank arches supported on pillars. These are common, running round the base of the walls on the interior, and are employed in many other situations, both externally and internally, so much so as to become a characteristic of the style. Another method of ornamenting blank walls is by diapering, or carving them in low recession after some small and recurring pattern, frequently in the form of square leaves, as in the triforia, Westminster Abbey.

Niches were in use at this period, but of a less elaborate character than those of succeeding styles. The figures were frequently set on small pedestals, and surmounted by a canopy consisting oftentimes of a three or five-foiled arch with plain pedimental head; in many cases, the canopies project or bow forwards. Niches are often placed in ranges of two or more, under one common arch, and in such cases are generally separated by single shafts.

Mr. Bloxam has subdivided this style into two, the earliest of which he names the *Semi-Norman* style. It is the same as that styled by others the *Transition* style, and embraces that class of buildings in which the round and pointed arches seem to be struggling for pre-eminence, and which bear evident marks of their near affinity to both systems: remarkable examples of the kind are the Church of S. Cross, and Malmesbury Abbey.

The general characteristics of this division consist in the use and combination of round and pointed arches in the same building; in some instances, pointed arches are surmounted by others of the semi-circular form, in others semi-circular arches are made to intersect, and thus form pointed arches. Another characteristic is the existence of pointed arches on massive piers of Norman design. The piers are mostly Norman in character and proportion, but have their capitals often ornamented with a simple description of foliage. In other respects, the details of such buildings are for the most part Norman.

Sometimes the piers are of more slender proportions, and attached to a large central pier, which is either square or round; and a still closer approximation to the Early English examples is shown in the horizontal bands surrounding the piers about midway.

The soffits of arches are frequently recessed, which shows an advance upon previous examples, but the chamfer common to Early English buildings is omitted, the edges being left square.

The Decorated style.

Otherwise termed, in architecture, the *Middle-pointed*, stands next in respect of time and decoration. It had its commencement in the reign of Edward the First, and arrived at maturity during the reigns of the two succeeding Edwards, from which circumstance the name of *Edwardian* has sometimes been applied to it. It dates from 1307 to 1377, or a little later, and may be named generally the style of the fourteenth century. This period of architecture is of all others the most beautiful; it rivals the preceding in chasteness, while it surpasses it in richness; and at the same time is free from the extravagant and redundant ornamentation of the succeeding styles.

The *arches* of this period are described from equilateral or obtuse-angled triangles, and in many instances are not easily distinguishable by their shape from those of the previous style; and in smaller buildings, where the soffits are merely recessed and chamfered without mouldings, it is a difficult matter to distinguish them at all; the date, however, may usually be determined by the mouldings of the caps and bases of the piers. In larger or more costly buildings, the arches are moulded, and the distinction marked by their contour. The mouldings consist of rounds projecting to the extent of from one to three-quarters of the circumference, and are frequently filleted, alternating with plain soffits and faces. As arches of decoration, the trefoiled was not uncommon. Hood-moulds frequently occur, and are terminated on heads or foliage.

The *shafts* of *piers* in small parish-churches are mostly of a simple circular or octagonal plan, similar to those of the preceding period, and, like the arches, are only distinguished by their capitals and bases. The alternate arrangement of the circular and octagonal piers is still adhered to. In larger buildings the piers are clustered, and consist of four or more shafts, which are in contour, either half or three-quarter cylinders. They differ from Early English examples in being attached to each other, whereas the latter are detached from each other, and frequently from the central shaft. The plan of these clustered piers is often that of a lozenge, or of a square placed diagonally; another shape is that of a quatrefoil, but many other forms are found which we cannot stop to mention. In many instances, we see four or more main shafts with smaller shafts introduced between them, and sometimes mere mouldings in the place of the secondary

shafts; in late examples, small shafts occur, separated by a deep hollow and two fillets, a form which prevails in the succeeding style, but in perpendicular examples the hollow is very shallow in comparison. In all the above cases vertical fillets are employed to a very large extent both upon the shafts and mouldings. In very large structures the piers are made up of a very great number of shafts.

The *capitals* are either bell-shaped or octagonal, and in clustered pillars usually follow the general form of the pier, but sometimes are continued in one sweep all round without any regard to the contour of the shafts. They are frequently only moulded, the prevailing mouldings being rounds, plain or filleted, ogees and hollows, in which some ornament, such as the ball-flower, is often introduced. The mouldings are not so deeply cut as in the Early English examples. In most of the clustered, and many of the single pillars, the vase is covered with rich and beautiful foliage placed horizontally, and consisting of very perfect and natural imitations of the oak, ivy, vine, &c., very freely and delicately executed. Some capitals are ornamented with sculptures of heads, figures, and such like. The *abacus* is either circular or polygonal in plan, and its mouldings are composed of rounds, frequently with an overlap, of ogees, and hollows. We have instances of continuous imposts in this style, where the mouldings of the pier are carried round the arch without the intervention of a capital.

There is great variety in the *bases* of this period. In plan they usually agree with the shaft, but are sometimes octagonal where the piers are circular, the mouldings following the contour of the pier, and overhanging the plinth; in some few instances the mouldings are raised on a square plinth. The plinths are frequently double, and of considerable height, the lower one projecting beyond the upper with a simple splay, reversed ogee, or hollow, with sometimes one or two small mouldings above. The base mouldings vary, but consist, for the most part, of reversed ogees or quarter-rounds, with the occasional insertion of one or two small rounds. In clustered columns the bases follow the general outline of the pier.

The *doorways* have one or more shafts in the jambs, which differ from the Early English examples in being constantly engaged. These have moulded or sculptured capitals, but the jambs are filled up with mouldings, which are continued round the arch without interruption. Many doorways are without pillars, being entirely composed of mouldings, which are continuous with those of the architrave, and are composed of a series of quarter-round and semi-cylindrical mouldings, the former being often filleted up the face. The hollows are frequently filled up with sculptured foliage, such as the ball-flower, or a square ornament placed at intervals, and sometimes with a running pattern of ivy or vine leaves, &c.; occasionally we find a series of niches carried up the jamb. The doorways are not usually so much recessed as those of the previous style, and the shafts are more slender, approximating more nearly to mouldings. In large buildings the arch is mostly pointed, but in smaller examples the ogee arch is not unfrequent, and the square-headed trefoil occasional: the architrave is usually moulded. The hood-moulds are seldom returned, but terminate in a head or knop of foliage. The arches are frequently surmounted by a triangular, or ogee canopy, which is finished with crockets and finials, and the spandrels filled with sculpture of various kinds. The doors themselves are often hung with ornamental hinges, as in the previous style, but the iron-work is of somewhat different design. In other respects the doors are mostly plain, though sometimes panelled and with tracery in the heads. The nails are often of an ornamental description, being of an hexagonal form, or made in the shape of a leaf or flower.

The *windows* of this period are usually of a large size, and of several lights, but there are also windows of a single light which are of a less elongated form than the Early English, and their heads are frequently trefoiled. Larger windows are divided into two or more lights by vertical mullions, but are seldom divided horizontally except in tall spire-lights, or in domestic edifices. These vertical mullions are carried up as far as the springing of the arch, and from that point branch out in various directions, interlacing and forming patterns of varied and beautiful design, known under the name of tracery. The variation from Early English practice is here distinctly marked, first in the employment of mullions in the place of shafts with capitals and bases, but more prominently in the method of filling the head or arch, of the origin of which we have taken notice above. In the earlier specimens the tracery is composed of circles, trefoils, quatrefoils, triangles, and other simple and complicated geometrical forms, arranged in various patterns, and is hence termed, geometrical tracery; but at a later period the lines assumed a more wavy or flowing appearance, and were disposed with greater freedom, such description of work being distinguished as flowing tracery. A very simple kind of window is that in which the mullions merely cross in the heads; and another of two lights with a simple trefoil in the head. This last approximates very closely to some Early English examples, but there is another kind which bears a close resemblance to the earlier specimens or triplets, and consists merely of three lights comprised under one arch, the centre one of which is higher than the two side ones, and separated from them by mullions. The subordinate arches formed by the intersections of the mullions, are generally foiled, as are also the principal compartments of the tracery; but there are some few exceptions.

The heads of the windows are principally two-centred pointed arches of various proportions; but segmental arches both simple and pointed, not unfrequently occur, as also does the ogee. Square-headed windows are by no means uncommon, especially in subordinate parts of the building, and have their heads filled with tracery, as in the other cases; some few, however, are entirely devoid of tracery. Common hood-mouldings resting on masks, heads, &c., are most frequent, but sometimes in rich examples we find pedimental and ogee canopies introduced, and ornamented with crockets and finials.

The mullions are most frequently simply chamfered, or in later examples slightly hollowed, but in more costly buildings each mullion is composed of a series of mouldings, set diamond-wise, and sometimes the hollows are filled up at intervals with some ornament peculiar to the style. In some cases we find shafts with capitals and bases still introduced, more especially against the jambs. String-courses are seldom omitted on the exterior beneath the windows. The windows are splayed on the interior, and the inner arch is frequently of a different form to that on the exterior, its edge being moulded or chamfered, similar to the practice followed in Early English examples.

Very beautiful windows of this style are to be seen at Exeter cathedral, almost every one of them being of a different pattern; the most elaborate, however, and the largest, is over the west entrance.

Circular windows filled with tracery are not uncommon in large structures, and are sometimes of excellent design. Windows in the shape of squares, trefoils, quatrefoils, spherical triangles, and sex-foiled circles, are common, but are of small size, and are usually seen in subordinate situations, such as clere-stories, gables, &c.

The more simple *buttresses* are not easily to be distinguished from those of other styles, consisting, as they do, of plain piers, with one or more slopes or set-offs without any further decoration; but in some cases they may be known from those of the Early English, by their position at the angles of buildings, where they are set diagonally. This, however, is not a very sure criterion, for some Decorated buttresses stand in the same position as those of the preceding style. In many instances the set-offs are finished with a pedimental head or gablet, which is sometimes plain, but more frequently foliated, and decorated with crockets and finials. In rich examples, the faces are often recessed for niches, which are surmounted by rich canopies, small buttresses, pinnacles, &c. The buttress seldom reaches above the parapet unless surmounted by a *pinnacle*, which is mostly of an elaborate description, being finished on all sides by a pedimental head similar to that above described, and the whole surmounted by an acute pyramidal top with crockets and finials.

The *parapet* is frequently embattled with plain or moulded capping, but very often consists of a plain horizontal cap. Some horizontale xamples are pierced or sunk in trefoils, &c., and very often with trefoils inserted in the spaces left on either side of an undulating moulding. *Corbel-tables* are of rare occurrence, but the parapet is usually finished on the under side by a cornice consisting of a roll-moulding, overlapping a deep hollow, in which are sometimes inserted ball-flowers, masks, and other ornaments.

The *roof* still continues of a lofty pitch, but somewhat more depressed than in the previous style. The larger churches are vaulted as before, but there is some difference in the arrangement of the ribs, which are greatly increased in number. Each bay or compartment of the vaulting is intersected, not only by longitudinal, transverse, and diagonal ribs, but these again are intersected by others in a variety of ways, so as to divide the vault into a greater number of cells, a practice which gives the roof a more complicated and richer appearance. Bosses of elegant design, and excellent workmanship, cover the intersections of the ribs, which are moulded, and the hollows frequently filled with the ball-flower ornament.

The same remarks apply to the wooden roofs of this period as to those of the preceding: we have but few examples now remaining, roofs of a later period having frequently been substituted in buildings of this style. The early roofs are doubtless of much the same character as the Early English, but in later examples there are some distinctions, although it is a somewhat difficult task to decide the exact date of any. In some examples the beams are merely chamfered as before, but in many they are moulded or have their edges foiled or cusped in such a manner that the spaces between the timbers present the appearance of some description of polyfoil. Tie-beams seem to have been of frequent occurrence in this style, and are often suspended by king-posts, which are sometimes but plain timbers, but at others assume the form of an octagonal shaft with moulded base and capital. Polygonal roofs having the timbers so disposed as to present to view a number of canted surfaces, are not unusual, they are mostly of six sides, but sometimes in later examples heptagonal. The principles of high-pitched roofs are frequently disposed in the form of an arch, and where tie-beams are employed, the same outline is preserved, by supporting them on curved braces, fixed to a wall-piece and resting on corbels. Longitudinal braces are frequently carried from the king-post of one principal to that of the next, and are often of an arched form resting at each end on tie-beams, and reaching to the ridge-piece at the apex, such arches being frequently foiled. A somewhat similar arrangement is adopted on the sloping sides of the roof, the purlins resting on arched purlin-braces, which stand upon the wall-plates, and are carried up under the common rafters. In some instances both king-posts and collars are employed, in others, king-posts with struts on either side, and occasionally queen-posts and straining pieces are introduced.

A curious roof of this date is thus described by Mr. Bloxam :—"In the little desecrated church of Horton, near Canterbury, is an open wooden roof, of a construction different to those which have been described. It is divided into bays by horizontal tie-beams, with the under parts moulded, resting on the wall-plates and on vertical wall-pieces supported on corbels, with a curved brace between each wall-piece and the tie-beam. From the centre of each tie-beam rises an antagonal-shaped king-post up to about two-thirds in height of the valley of the roof, where it supports a longitudinal rib or beam. From the principals of the roof, at about two-fifths in height, spring plain braces, which cross diagonally just above the longitudinal rib, and rest on the opposite principal. Above these there is neither collar-beam nor apparent ridge-piece. From four sides of the king-post spring curved braces, both longitudinal and lateral; the former support the longitudinal rib, the latter the braces which cross above it. The roof is high-pitched." Other examples of this or a similar description occur, and the arrangement of curved braces springing from the four sides of the king-post are not uncommon.

In the richer class of roofs the spandrels formed by the intersection of the timbers are frequently filled with tracery.

The general arrangement of the *towers* is similar to that of the previous style, the greatest differences appearing in the apertures and decorations. The windows of the lower stories are many of them of small dimensions, and of single lights with ogee or foliated heads, and label or square hood-mould. The belfry-windows are the most important features, and are arranged singly or in pairs; they are of a large size, frequently filling up the entire story. The largest window, however, frequently occurs on the west face of the lower story, or that above the entrance, and forms one of the general range in the interior of the church; it is often of very large dimensions and elaborate design, standing in this respect next to that in the east wall of the chancel. Blank arcades are not so much in vogue as in Early English examples, and when used are of a form and decoration common to the period.

The *spires* are very acutely pointed, but in some cases are very low, forming merely a low pyramidal roof to the tower: the latter is mostly constructed of wood, a material frequently employed in the construction of the loftier kinds, which in larger structures, however, are almost universally of stone. The large spires boast a larger number of spire-lights than those of earlier date; and not only so, but they are of a more elaborate description, being capped by lofty pediments enriched with crockets and finials. They are also sometimes divided into a number of compartments by horizontal bands of panelling, and the angles of the spire enriched with crockets running all the way up, and terminating in a large finial. The tower is mostly finished with a parapet, which is either plain or embattled, and sometimes pierced in quatrefoils, &c., and is supported on a moulded cornice, the hollows of which are often filled with the ball-flower or some other ornament. At the angles we frequently find projecting gurgoyles in the form of animals, &c. Pinnacles of a prominent and elaborate character are of constant occurrence, and sometimes behind them rise ornamented flying-buttresses to support the lower portion of the spire. Parapets and gutters, however, are not universal, for we not unfrequently meet with broach-spires of this period.

The *mouldings* consist for the most part of a greater number and variety of members than those of the Early English style. Rounds and hollows still prevail, but the latter are not so much undercut as before; in the earlier examples they are still deep, but grow more shallow towards the termination of the style. Quarter, half, and three-quarter rounds are most prevalent, and are often filleted and separated by small hollows; ogees, too, are of frequent occurrence, as are also ovolos and cavettos. Another undulating moulding, similar to that in use in the next period, but of somewhat different projection, is also used, and is in appearance somewhat like a double cyma, consisting of a convexity in the centre between two hollows. The roll-moulding, in which the upper half overlaps the lower, is in constant use. Rounds and hollows are sometimes separated by fillets, but frequently run into each other without any interruption.

For string-courses, the overlapping roll-moulding is very common, but sometimes a simple roll or a roll filleted, or what is termed keeled, is used in its place; the latter term being applied when the roll comes to a sharp edge in the centre. These mouldings are used either separately, or with other subordinate ones; a hollow is not unfrequently carried underneath. Hood-moulds are formed of quarter-rounds or ogees with a hollow or plain chamfer beneath, and are seldom returned. The base-moulds consist of one or more slopes with or without a projecting edge, the whole being surmounted by a filleted or keeled round. In all the above cases the ball-flower and other ornaments are often inserted in the hollows and carettos.

The leaves selected for imitation in the *foliage* of this period, are those of the oak, vine, ivy, fern, white-thorn, &c., which are copied with a boldness and freedom not common in previous examples. They are also more naturally disposed, and have a less stiff and formal appearance than those of any other style; there are not so many sudden projections, and the outline is of a more gently undulating form than in the Early English specimens: in capitals, the stems are twined about in various directions, instead of rising vertically from the neck.

The most usual and characteristic of the ornaments is the ball-flower, which consists of a round ball enclosed within a flower of three or four petals, the ball appearing beneath the slight opening of the petals; it is supposed by some to represent a rose-bud. It is used in almost every situation, but more especially in the hollow mouldings of jambs, arches, cornices, &c., in which it is inserted at intervals. Another ornament consists of an open square flower of four leaves, with a small ornament in the centre, which is employed in the same manner as the preceding; but a series of them is sometimes used, the flowers being placed in contact with each other, in which manner it is frequently applied as a diaper. They are sometimes introduced alternately with the ball-flower. A representation of a very beautiful ornament which occurs at Adderbury, is given by Mr. Bloxam in his manual. It bears some affinity in form to the dog-tooth moulding, and consists of four ivy leaves placed in the angles of a square, with their upper sides to the wall, the stems projecting outwards, and meeting in one point, which gives the ornament a pyramidal form. Leaves, masks, heads, &c., are often used in similar positions.

The crockets of finials are of various descriptions, but are readily distinguished from the Early English by their natural and flowing outline, and by the crumpled leaves, so different from the crisp appearance of the latter.

The *niches* are of a very elaborate description, and are usually of a considerable depth, having the roof covered with minute ribs and bosses. They are almost always surmounted by pedimental or ogee canopies, which are sometimes bowed forward in the form of an ogee, and are almost always decorated with crockets and finials. The arches are foliated, as are also frequently the spandrels above them. Some niches have conical coverings like spires crocketed at the angles, and surrounded with a series of canopies one on each face of the spire. The sides, too, are often enriched with small ornamental buttresses. Some again have flat tops.

The *Perpendicular* style dates its rise towards the close of the fourteenth century, at the latter portion of the reign of Edward III., and prevailed until the disuse of Gothic architecture. It is characterized by the exuberance and redundancy of its ornaments, and is wanting in the simplicity of the Decorated style. In the earlier examples, this enrichment is not carried beyond bounds, but in later times it becomes excessive, and the chief aim of the architects seems to have been to employ as much labour as possible on decoration. This practice proved injurious, and at last fatal, and Gothic architecture may date its decline from the commencement of the fifteenth century.

This style is called by some *Third-pointed*, and by others *Florid*. The term *Perpendicular* was given to it on account of the peculiar arrangement of the tracery in window-heads, which forms a very marked characteristic of the style; but some have objected to the name, as of only partial application, and suggest the term *Horizontal*, as being much more appropriate and significant of the general tendency of the style; and in this they are certainly correct, as witness the depressed arch, low-pitched roof, square-headed windows and door-ways, square hood-moulds, and the horizontal transoms. But on this subject we shall not here enter; the term is well established, and could not readily be laid aside, supposing such a course to be desirable.

Pointed *arches* of all descriptions are to be met with in this style, nor do they differ materially from those of the preceding period, but drop arches are perhaps more prevalent. An arch of a peculiar kind, however, began to be used some time ere the close of the style, which is not to be found in any other; it is described from four centres, two of which are on the springing line, and describe arcs of very small radii, and the other two at some distance below it. Such arches have a very depressed appearance, the rise above the springing line being inconsiderable when compared with that of the two-centred arches; the rise, however, varies to some extent in different examples. This arch is termed the Tudor arch, and was introduced about the middle of the fifteenth century. Ogee arches are of constant and universal occurrence, and foiled arches are very frequent in decorative work.

Arches are very frequently moulded, but in the plainer examples are only recessed and chamfered. The mouldings consist of much the same members as before, but they are of a less prominent character; the hollows are more shallow, and the projecting mouldings less prominent: the contour is of an undulating appearance, the junctions of the different members being but indistinctly marked. A large but shallow cavetto is of frequent occurrence, and is sometimes ornamented by the insertion of a square flower at intervals. The soffits of some arches are ornamented with panelled work.

The *shafts of piers* are sometimes simple octagons in plain, as in the preceding styles, but are not of such frequent occurrence as before, and sometimes differ in contour, having the sides of the octagon slightly concave; they may be distinguished from earlier examples by their capitals and bases. Clustered piers are very frequent, and their general

plan is that of a square set diagonally, but the breadth of the pier between the aisles is frequently greater than the depth between the arches. They are composed of four or more slender shafts, engaged, with hollows, ogees, and fillets intervening. A very common arrangement presents a section of the form of a square, having its angles cut in a broad but shallow concavity, and the four sides or flat faces ornamented with a half or three-quarter round shaft attached, and projecting beyond the face. This shaft does not occupy the entire face, but leaves a flat surface on either side; it is finished with distinct cap and base, but the surface and concave angles of the parallelogram are frequently continued round the arch without interruption. When piers are placed diagonally, the angles are often ornamented with slender pillars with caps and bases, while the intermediate spaces, which constitute the main body of the pier, are moulded and continued uninterruptedly to the apex of the arch. The sub-shafts are sometimes the only ones furnished with capitals, the face-shafts being carried up to the whole height of the building to the wall-plate without caps, but sometimes the shaft is continued above the capital. Three or more shafts clustered together are not unfrequently found at the angles in the place of the single one above alluded to.

The plan of such small shafts is commonly circular and plain, but they are sometimes filleted, and occasionally polygonal, with concave sides. The piers are not unfrequently composed of mouldings only, and these carried up continuously, without capital or any other projection, to the apex of the arch; and where arches are neither moulded or recessed, the sides of the pier and soffits of the arch are usually enriched with panel-work.

Capitals are either circular or octagonal, but the necking is usually of the former, and the upper members of the abacus almost invariably of the latter form, whether the capital and its mouldings be circular or octagonal. The vases are mostly plain, but sometimes enriched with foliage, which is of a more conventional form than in the previous style. The mouldings consist of ogees, rounds, beads, and hollows, the second and fourth of which are frequently combined without forming edges, and have a bead underneath. The top of the abacus is often splayed, and sometimes ornamented with a crest of small battlements: the sides are occasionally hollowed out. In clustered piers, the capital is sometimes carried all round without interruption, and the vase covered with foliage, but more frequently the capital of each shaft forms a separate and distinct member.

The *base* mouldings are usually set upon a lofty polygonal plinth, which is sometimes double; the lower one projecting, and the projection moulded with a hollow or reversed ogee. The upper members of the base-mouldings follow the form of the shaft, but the lower ones are often polygonal, like the plinth which they overhang. In clustered piers, the bases are mostly treated separately, as is the case with the capitals, but sometimes the mouldings are continued all round, as are the plinths almost invariably.

The earlier *doorways* of this style have two-centered pointed arches, but the most common and characteristic form is the four-centered: for smaller doorways, the ogee is sometimes used. The two centered arch is often surmounted by an ogee-shaped hood-mould, enriched with crockets and finials, but some of them, and nearly all the four-centered, are enclosed within a square head formed by the outer mouldings, with hood-mould of the same form, the spandrels being filled with quatrefoils, flambeaux, roses, shields, &c. Sometimes, however, the hood-mould follows the form of the arch, even in the four-centered examples. The hood-mouldings are often returned horizontally, and when not so, terminate at the springing of the arch, on heads, shields, &c., or have the mouldings twisted round in the form of a lozenge, or circle, with some little ornament in the centre. The hood is usually placed immediately above the apex of the arch, but in some specimens it is considerably elevated, the intermediate space above the spandrels being filled with quatrefoils, or other panelled work; the upper members of the hood sometimes coincide with the lower portion of a string course. Double doorways are of very rare occurrence.

The jambs are not unfrequently ornamented with shafts with caps and bases, but they are mostly small, and often not well defined, except by the capitals and bases; in many instances all the mouldings are continued round the arch, without apparent impost. Large hollows are very frequent amongst the mouldings of doorways, and are occasionally filled with foliage or other decoration.

The doors themselves are often covered with panel-work of a rich description, and sometimes with tracery in the head. The smaller doors are often weather-boarded, without any ornament; the iron scroll-work being rarely employed at this period.

The *windows* of this style are easily distinguished from all others, by the vertical disposition of the tracery in the heads; the mullions of the lights, instead of branching out at the springing into flowing lines, are continued vertically to the intrados, and secondary mouldings are continued in the same direction from the centre of each light, and converge once or twice ere they reach the arch. The principal and subordinate lights are all arched and foliated, the principal being frequently divided horizontally by transoms, which are a further characteristic of the style. Windows which consist of several lights are divided into two or more compartments, containing each two or more lights, and these are frequently arched over in the heads. The transoms are often finished at top with a small ornamental battlement; and the mullions present a concave outline. The heads of windows offer a great variety of form, some being two-centre-pointed of various degrees of acuteness, others four-centred, others again segmental, triangular, and square-headed. Windows of the last class are very common, having perpendicular tracery in the heads; they are frequent in clere-stories, where we also find circles and quatrefoils used for the same purpose.

The plainer *buttresses*, are similar to those of the preceding styles, consisting of one or more projections, with plain faces and set-offs, frequently terminating in a slope under the parapet, but sometimes finished with a crocketed pinnacle. In the richer examples the faces are covered with panel-work, and are finished with square pinnacles, sometimes set diagonally and terminated with a crocketed spire, or finished with an animal or such like ornament.

The *parapets* are often embattled, and have usually the coping carried all round the embrasures; the plain surface down as far as the cornice, is not unfrequently panelled or pierced in quatrefoils, foiled-arches, &c. The top of the parapet is as often horizontal, and either plain or covered with sunk or pierced ornaments, consisting of trefoils and other polyfoils inserted within square, circular, or triangular compartments. The cornice consists of a few mouldings, the most prominent of which is frequently a large shallow cavetto, which is often enriched with flowers placed at intervals.

The early *roofs* of this style are of a moderate height, but later examples are of very low pitch. The vaulting is still more complicated than in the preceding style; the number of ribs is increased, and they are frequently disposed so as to form geometrical patterns, as in the choir of Oxford cathe-

dral, and in many other examples. A kind of vaulting peculiar to the later period of this style, is termed fan-tracery vaulting. In it several ribs diverge at equal angles, and in all directions, from one bearing-post, and spread on the roof in the form of a circle, the entire figure having somewhat the appearance of a semi-cone: all the ribs preserve the same curvature. These spring from either side of the roof, and often meet in the centre, or the space left between, as also the spandrels are filled with ribs, forming geometrical tracery; when, however, a large space intervenes, it is frequently occupied with pendent figures of the same description, forming a kind of inverted cones suspended from the roof, the surface of which, like those at the sides, is covered with divergent ribs, and richly panelled. Roofs of this kind are more frequent in small structures, such as chantries and the like, but we have magnificent specimens of a grander description in Henry VII.'s chapel, Westminster, St. George's, Windsor, Peterborough cathedral, and some few other churches.

The wooden roofs of this period are more numerous, and more readily defined, than those of any previous era. Their increased number arises probably from a practice common at the time, of substituting more enriched roofs in the place of plainer examples of earlier date, a practice which is often evinced by the form of a more highly-pitched roof than that existing, being still visible on the tower, against which it abutted. The majority of examples of this style are of a very low pitch, so much so as sometimes to be entirely hid on the exterior of the building by the parapet; but roofs of a lofty pitch are by no means uncommon.

In the loftier examples tie beams are not used, but the principals are usually connected by a collar beam immediately below the ridge, or by a block-collar completely filling up the angle of the ridge; where the collars are in a lower position, a king-post is sometimes carried from them to the ridge-beam. The collars are often ornamented with mouldings or small battlements, which have a very good effect. A simple form of roof consists of principals of stout planking resting on corbels, and cut in the form of an arch, with block collars underneath the ridge, as at Stourbridge church. Sometimes arched planking of this kind is supported on projecting hammer-beams, with curved braces underneath resting on corbels, which method gives the outline of the entire roof the form of a trefoiled arch either round or pointed. A similar form is often constructed of the usual timbers, and springs from the level of the wall-plate, without curved braces, as at Athelhampton Hall, Dorset.

Tie-beams are sometimes used in roofs of this kind, supported by braces resting against wall-pieces, and these again, on corbels or shafts, the spandrels being often filled with tracery. The principal rafters above the tie-beam frequently consist of planking of arched outline, pierced with quatrefoils, &c., as at Malvern Abbey. Some roofs again are constructed without principals, the common rafters being tied at the top with a collar-beam resting upon timbers disposed so as to form a circular arch, the lower extremities of which rest upon hammer-beams.

The hammer-beam is peculiar to this style, and is found employed to a very great extent in the large hall-roofs of the period. A very common form for these roofs consists of two principal rafters tied at the upper part with a collar-beam, under the extremities of which are two queen-posts resting on hammer-beams, and these again on curved braces. The latter are fixed to wall-pieces, which stand on corbels at some distance down the walls. Arched braces are frequently carried from the end of the hammer-beam to the centre of the collar, which is sometimes suspended by a king-post. Some examples have two sets of hammer-beams, one above the other, as at Hampton Court, where the roof is a sort of curb; it is very strong, but composed of many timbers, which are somewhat complicated in their disposition. We must not pass over unnoticed, the roof of Westminster Hall, which is one of the most magnificent in existence. Its principal feature is an arched rib composed of three thicknesses of timber, which completely spans the building, and is carried down below the top of the walls to the corbels. Immediately above the apex of this arch is a collar-beam, having in the centre a king-post reaching to the ridge, and at the sides two queen-posts with a straining piece. The hammer-beams are carried out beyond the line of the arch, and are supported at the extremities on curved braces resting on the corbels, a similar curve being also carried upwards to touch the large arch so as to form by their combined outline a trefoiled arch. Above the ends of the hammer-beams rises an upright or queen-post, which is carried up to the end of the collar, and supports the principal rafters at about midway. This, as also most roofs of the kind, is moulded and enriched with perforated panel-work, and other ornaments; the hammer-beams are often carved into representations of angels bearing shields, musical instruments, &c.

The obtuse low-pitched roofs peculiar to this period, are often framed with tie-beams and king-posts, with curved bracing-ribs underneath, resting against an upright wall-piece supported on a corbel; the braces being mostly curved in the form of an obtuse arch. The spandrels are often filled with open tracery, as are also the spaces above the tie-beams. Sometimes roofs of an exceedingly low pitch, or even perfectly flat, are formed without any truss whatever, consisting only of principal and common rafters, and purlins, without either tie or collar beams. In such cases the principals are often supported at the end by upright wall-pieces resting upon corbels at a considerable distance below the wall-plates, and from the foot of the wall-pieces curved braces are carried up to the centre of the principals. These braces are often solid, constructed out of a piece of stout planking and entirely filling up the spandrels.

The sloping bays of low-pitched roofs are often divided into square compartments by purlins and common rafters, the former being increased in number, and the latter placed at a greater distance apart than usual. The intersections of the timbers are almost always covered with ornamental bosses, and the timbers themselves richly moulded. Sometimes these compartments are subdivided by other secondary mouldings, with bosses likewise at the intersections. The larger beams in almost all these examples are moulded, and the horizontal timbers, such as wall-plates, ties, and collars, are often enriched with small battlements, or have the mouldings ornamented with some decoration peculiar to the period.

The *towers* are frequently constructed on a very grand scale, and are very often devoid of spires, being occasionally surmounted by octagonal lanterns, as at Boston, Lincolnshire, where the tower is of great height and magnificence. Another very beautiful and lofty example occurs at Dundry, near Bristol, but in this case it is finished at the top by four little square turrets, placed one at each angle; the turrets, as also the lofty battlemented parapet, being pierced in panel-work, a practice very common in parapets of this period. At Magdalen College, Oxford, is another very beautiful example, the corners of which are finished above the battlements with octagonal turrets or pinnacles, carried up from the ground in the shape of buttresses; another buttress is carried up the centre of each face, and is finished above the parapet with a pinnacle of smaller dimensions. Another ornament in this example is of common occurrence, and consists of bands of sunk quatre-

foils or other ornaments. In smaller churches the tower is often finished with a plain parapet or simple battlement, but it is a very prevalent practice of the period to carry up a polygonal stair-turret at one angle, which rises some feet above the general level of the tower, and forms a very picturesque object. The windows and general arrangement of the towers are much the same as in the last style, differing only in matter of detail; square-headed windows are of frequent occurrence, and often appear in the belfries, especially in that class of towers just alluded to.

Spires are not so frequent as in other styles, and are never what are termed broach-spires, the tower being invariably crowned by a parapet. Where spires occur, they are of the same form and general description as before. They are often supported at their angles by flying-buttresses, springing from the corners of the tower. The angles are also frequently crocketed.

The *mouldings* of this period are in general flatter, or of less projection, and therefore less effectiveness, than those of previous styles. There is also a greater prevalence of angles or corners. Round and hollow mouldings are often connected without any apparent line of separation; but members of a different description are separated by either quirks or fillets. A large shallow concave moulding is very prevalent, and forms a characteristic mark of the style. It appears very often in archivolts and cornices, and is often enriched by the insertion of flowers, leaves, and other ornaments. Ogees are perhaps more frequently used than any other kind of mouldings, but rounds, beads, and cavettos are of very common occurrence. An arrangement of ogees in close contact, with the convex sides next each other, is of constant occurrence, and is characteristic of the style. A moulding of an undulating contour, being convex in the middle, and concave on either side, is common in abaci and dripstones, as is also the reverse of this, the hollow being in the middle, and the convexity on either side. Fillets are used, but are not often applied to larger mouldings. In general, it may be observed, that in all cases the mouldings of this style are more flat, the hollows and projections approaching more nearly to a straight line.

The *ornaments* used, consist mainly of detached flowers or leaves usually of a square outline, of running patterns and bunches of foliage, of grotesque heads and figures of animals; of shields, and various kinds of heraldic devices. The rose, the badge of the houses of York and Lancaster, is a characteristic ornament, as is also a lozenge-shaped leaf, supposed to represent the strawberry-leaf, and generally known under the name of the Tudor flower. The foliage is very elaborately and delicately carved, but does not exhibit the same amount of freedom of design or execution, which is manifest in the earlier styles.

The *walls* are often covered internally, and sometimes externally, with panel-work tracery, which is a characteristic feature of the style.

The *niches* of the period are somewhat similar to those of the Decorated style, but sometimes consist of mere recessed panels. They are usually, however, either octagonal or sexagonal in plan, with vaulted covering. Of canopies, some are flat, and others projecting; the latter being either semi-circular, or polygonal in plan, and either finished horizontally, or capped with a small spire or bell-shaped roof. The angles are occupied with buttresses and pinnacles, the latter being sometimes suspended from the overhanging covering, which is enriched with crockets and finials, and other ornaments in profusion.

With the commencement of the Reformation, the practice of Gothic architecture may almost be said to have ceased, as did all ecclesiastical building to a very great extent. The sacrilegious plunder of Henry VIII., his destruction of the monasteries and religious houses, and the wholesale spoliation and destruction of the works of antiquity which was carried on under his orders, tended to discourage persons from the erection of churches or religious edifices, and the art was soon entirely lost. The introduction of the Italian style assisted greatly in the overthrow of a mode of building which had been in vogue some three or four hundred years. Pure Gothic architecture may be said to have ceased about the middle of the sixteenth century, but it still retained some influence for a few years later. The method of building adopted during this interval, has been fitly denominated the *Debased*.

The characteristics of this style, if it may be so termed, may be briefly enumerated as follows:—The windows are square-headed, divided into bays by perpendicular mullions, the heads of each bay being frequently left square, but sometimes obtusely-arched, and occasionally foiled. The mullions are plain and unfinished, without mouldings of any kind, and all the workmanship is of a very inferior kind. Hood-moulds are often, but not always, used.

The *doorways* are either obtusely-pointed, or round-headed with prominent key-stones. In late specimens, many of the features of Italian architecture are introduced in details and construction. Examples of the Debased style exhibit a poverty of design and clumsiness of execution, in comparison with those of previous styles, which will at once decide their date and position.

In the above sketch, we have made no allusion to Continental Gothic; our remarks and descriptions having been entirely confined to the style as developed in our own country; nor have we space here to treat of the former separately. We can only refer to those writers who have treated this subject specifically, amongst whom the following names stand pre-eminent. Whewell's Architectural Notes on German Churches; Willis on the Architecture of the Middle Ages in Italy; and Moller's Memorials of German Gothic Architecture.

From this article, we refer to the words CHURCH, CATHEDRAL, ECCLESIASTICAL ARCHITECTURE, and to various articles of the same nature.

GOUFING FOUNDATIONS, a term used in Scotland, and particularly at Glasgow, for the under-pinning of a wall when found insecure.

GOUGE, a concave and convex chisel, the section of which is the frustum of the sector of a circle, serving to cut a concave excavation in wood or stone. The basil is made from either the concave or convex side.

GOWT, or GO-OUT, in engineering, a sluice used in embankments against the sea, for letting out the land-waters when the tide is out, and preventing the ingress of salt water.

GRACES, GRATIÆ, or CHARITIES, in the heathen mythology, were fabulous deities, and represented as three young and handsome sisters, attendant on Venus.

Their names are Aglaïa or Ægle, Thalia, and Euphrosyne; *i. e. shining*, *flourishing*, and *gay*. They were supposed by some to be the daughters of Jupiter and Eurynome, the daughter of Oceanus, and by others to be the daughters of Bacchus and Venus. Vossius *de Idol.* lib. xiii. cap. 15. Homer (*Iliad*, lib. xiv.,) changes the name of one of the Graces, and calls her Pasithea; and he is followed by Statius. (*Theb.* lib. ii.) Some will have the Graces to have been four, and make them the same with the *Horæ*, *Hours*, or rather with the four seasons of the year.

The Lacedæmonians admitted only two of them, whom

they worshipped under the names of Klyta, Kleta, or Clita, and Phænne. The Athenians allowed the same number, but denominated them Auxo and Hegemone.

A marble in the king of Prussia's cabinet represents the three Graces in the usual manner, with a fourth seated, and covered with a large veil, with the words underneath, AD SORORES IIII. Yet Mons. Beger will by no means allow the Graces to have been four: the company there present, he understands to be the three Graces, and Venus, who was their sister, as being daughter of Jupiter and Dione.

They are always supposed to have hold of each other's hands, and never parted. Thus Horace, (lib. iii. od. 21.) describes them:

"Segnesque nodum solvere gratiæ."

They were also represented in the attitude of persons dancing; whence Horace says (lib. i. od. 4):

"Alterno terram quatiunt pede."

They were commonly thought to be young virgins. In the earlier ages they were represented only by mere stones, that were not cut; but they were then represented under human figures, at first clad in gauze. The custom of giving them drapery was afterwards laid aside; and they were painted naked, to show that the Graces borrow nothing from art, and that they have no other beauties than what are natural.

Yet, in the first ages, they were not represented naked, as appears from Pausanias, lib. vi. and ix., who describes their temple and statues. They were of wood, all but their head, feet, and hands, which were white marble. Their robes or gowns were gilt; one of them held in her hand a rose, another a die, and the third a sprig of myrtle.

They had temples, as we learn from Pausanias, at Elis, Delphos, Perga, Perinthus, Byzantium, and in several other places of Greece and Thrace. The temples consecrated to Cupid were likewise consecrated to the Graces: and it was also customary to give them a place in those of Mercury, in order to teach men, that even the god of eloquence needed their assistance. Indeed, some authors reckoned the goddess of Persuasion in the number of the Graces, thus intimating, that the great secret of persuasion is to please. The Muses and the Graces had commonly but one temple; and Pindar invokes the Graces almost as often as he does the Muses. Festivals were appropriated to their honour through the whole course of the year, but the spring was chiefly consecrated to them as well as to Venus. Greece abounded with monuments sacred to these goddesses; and their figures were to be seen in most cities, done by the greatest masters. They were also represented on many medals. The favours which these goddesses were thought to dispense to mankind, were not only a good grace, gaiety, and equality of temper, but also liberality, eloquence, and wisdom, as Pindar informs us; but the most noble of all the prerogatives of the Graces was, that they presided over all kindnesses and gratitude; insomuch that, in almost all languages, their names are used to express both gratitude and favours.

GRADATION, (from the Latin, *gradus*, a degree,) in architecture, an artful disposition of parts, rising as it were by steps or degrees, after the manner of an amphitheatre; so that those placed before do not obstruct the view from those behind.

The painters also use the word *gradation* for an insensible change of colour by the diminution of the tints and shades.

GRADATION, in painting, relates both to chiaro-oscuro and to colour: that is, all the different degrees in which light and dark, and colour, may be modified, are comprehended in it.

An object receding from the light, and gradually losing it, becomes at its farthest extremity obscurely defined. A coloured body, pure or bright in tint, under the same circum stances, gradually diminishes in clearness of hue throughout its receding parts, and becomes dull and dark. By fixing the scale of gradation in both these particulars, effects of great force or great simplicity may be produced. The scale of descent being made rapid, great force will ensue, from the strong oppositions it promotes; and the reverse will take place when the degrees of descent are prolonged, and less contrast thereby effected. The nature of the subject, and the situation of the figures with regard to light, must be the artist's guide in this matter.

The gradation of colour includes not only the different degrees of purity, or brilliancy of the same colour, but also the approximations of each colour to its neighbour, necessary to produce harmony; and also the art of gradually losing the local colour in obscurity, and yet maintaining its character in the object; which is extremely difficult, and of great importance, in the art of painting.

GRADETTO, GRADETTI, or ANNULI. *See* ANNULETS.

GRADIENT, in engineering, a term indicative of the proportionate ascent or descent of the several planes upon a railway, thus: an inclined plane four miles long, with a total fall of 36 feet, is described as having a fall of 1 in 586$\frac{2}{3}$, or 9 feet per mile. Mr. Macneill suggested the word CLIVITY, as a more appropriate term than gradient; and its compounds, *acclivity* and *declivity*, are very comprehensive and significant.

GRAFTING TOOL, in engineering, a kind of spade, used by *navigators* in railway and canal works; it is made very strong and curving; often called only a *tool.*

GRAIN, the plates of wood or stone, in the direction of which it may be split into various thicknesses.

GRAIN, in mining, is applied by quarry-men and masons to the minute figures in most blocks of stone, by which they are disposed to split more easily in some certain direction, than in any other, as wood is disposed to split in the direction of its grain. *Beat*, *sheet*, *lamella*, and *stratula*, are other terms of almost similar import. Experienced masons can generally discover the grain of the most homogeneous or perfect freestone blocks, or such as will cut with equal ease in any direction. This they often do, by observing the directions of the very minute plates of mica, or silver, as they call it, which are frequently found arranged in the stone, in the direction of the grain, or beat of the stone; which, it must be observed, is not always that of the beds or stratification, many rocks having stratula which cross their beds obliquely, often at an angle of from 30 to 45 degrees with the bed or plane of the stratum; and such stratula not uncommonly dispose the stone to split into flags, or paviers, or even tile-stones, or slates for houses, and into the most thin and perfect lamina. Sometimes these oblique stratula cross stone beds of very great thickness, and have been frequently mistaken, by inattentive observers, for the stratification itself.

GRANARY, a building contrived for laying up and storing corn, in order to preserve it for a length of time.

The construction of this class of buildings has not, we believe, received that attention which the importance of it deserves, and we consider therefore that some account of the proper mode of designing and erecting granaries on scientific principles will be both interesting and useful.

It must be evident to all, that, owing to the uncertainty of harvests, the produce of a year may be either abundance or dearth, the frequent recurrence of the latter, in the earlier ages, obliged most of the ancient nations to seek means

of preserving the superabundant produce of plentiful years, in order to be prepared against the privations of less fortunate ones. This necessity was more imperative, when the means of conveyance by land and water were less perfect than at present. In modern times a higher state of civilization has taught mankind to feel the advantages of a free circulation of produce, famine is not now therefore so fearful an evil as formerly. The improvements in the mode of culture have also much increased the produce of the earth; but the probabilities of famine, though decreased, still remain to a certain extent, and the construction of proper repositories for storing up grain must be always important, as a means of lessening its evils.

In some countries public granaries are established upon a very large scale, and in them is preserved the grain collected from the whole of the surrounding districts. The French have given great attention to the subject, and the following plan for a public granary, by an eminent French engineer, is well worth imitation. M. Bruyere observes, that in the calculations necessary to fix the dimensions of a granary destined to contain a determinate quantity of grain, the following considerations must be attended to.

A granary of reserve, as it is termed in France, contains wheat of different ages, and the duration of their preservation is three years, the grain being supplied by thirds every year. The disposition to ferment being caused by the degree of moisture, and by the quantity, and the oldest corn being the dryest, it follows that the mean depth of the heap should vary with the age of the corn. From these data, and by the help of experience, the depths of the heaps of corn may be fixed as follows:—

Corn of one year	$19\frac{1}{2}$	inches.
" " two years	24	"
" " three years . . .	27	"

A distance of about a yard should be left between the foot of the heaps and the wall, and an empty space of thirteen to sixteen feet between the heaps, for the operation of turning. To these spaces must be added also those occupied by the staircases, rollers, trap-doors, working-rooms, &c., and the whole must be deducted from the superficial content of each floor. The remainder, multiplied by the number of stages, and the mean height of the heaps, will give the solid content of wheat that the granary can contain.

The situation of a public granary is important; if possible it should be placed near a canal or navigable river, in order to receive or send out the grain by water, or by any other easy method of transport, as the expense is thereby much diminished.

For the same reason, granaries should be near a sufficient quantity of mills, whose motive power can, in certain cases, be applied to the different machines used in the manipulation of the corn. These mills should not, however, be placed in the same building with the granaries, or be too near to them on account of the danger of fire, and because the two operations are hurtful to each other; the dust of the wheat injuring the flour, and the motion of the water rendering the grain too moist.

The aspect of granaries should be south, as the change of temperature will then be sufficient to keep a current of air between the opposite openings, and it is most important to use the driest winds for ventilating and drying the grain.

In order to diminish the extent of granaries, it is necessary to add to their height, by multiplying the number of floors; and, as it is easy to raise the grain by the help of machines, we thus gain the advantage of being able to make it descend

from sieve to sieve, which cleans and sorts them in the least expensive manner.

The lowest floor, should be sufficiently elevated above the earth to prevent damp, and to facilitate carting. Experience has proved that a height of 8 feet is sufficient for the curve that is described by the wheat when thrown up by a shovel. Each floor should therefore have a height of 10 feet.

The walls of the granary should be thick, not only on account of strength, but also to keep out damp and heat. The windows should descend to the level of the floor, so that the air may circulate through the lowest part, and strike the foot of the heap of grain. The entrance of the air is facilitated by widening the openings from the interior to the exterior. They should be grated with iron wire to prevent the entrance of birds, and furnished with shutters which, when open, fall back on the thickness of the wall.

When the granary is of considerable size, it appears natural to place the entrance in the middle of its length. This entrance should be large enough to permit vehicles to cross the building, so as to load or unload under cover. To prevent the division of the lowest floor, this passage is sometimes made by a projecting porch, under which the vehicles can be ranged, though in a less convenient manner. The staircases should be placed, near the passage, for the carts, but, to prevent interruption of the heaps of corn, some place them in a projection opposite the porch, or in one of the angles of the building.

It is desirable that granaries should not be of too great an extent, in order that the grain may more readily dry by the currents of air. On the other hand, as it is always necessary to reserve the passages along the walls, the size of the interior should not be less than 40 feet, or exceed 65 feet. In all cases, they are divided by pillars of stone, wood, or cast iron. (*Bruyère Etudes Relatives à l'árt des Constructions.*)

The following may be taken as a guide for the erection of a granary in this country. The building should be rectangular in plan, the height about twice the distance between the opposite walls, that is, 20 feet high by 10 feet in width on each side, and provided with numerous air-holes, declining outwards, to prevent the entrance of rain or snow. From each air-hole to a corresponding one on the opposite side, should be fixed an inverted angular spout or gutter, to permit the air to pass through unimpeded by the corn lying about; as many of these gutters should be fixed, as there are holes to receive the ends after crossing the building; and the extremities of the holes should be covered with wire gauze, to defend them from vermin.

The first floor of the granary should be divided into a series of hoppers, these hoppers to empty themselves into one large hopper underneath, provided with a sliding door to regulate the passage of the grain into a sack or other receptacle. At the top of the building a loft should be erected, to which the corn may be first hoisted by a tackle or crane, and be discharged over a cross-bar into the body of the building, which operation may be continued until it is filled to the top. Upon drawing off any corn at the bottom, the whole of it will be put in motion, and the airing of every part promoted; the process of airing should, however, be continually going forward through the numerous passages under the inverted gutters, the angles of which do not fill up by the lateral pressure of the grain.

GRAND STAIRCASE, the principal staircase of a large edifice, for the use of the family and visitors. *See Staircase.*

GRANGE, the ancient name of a barn; sometimes applied to the farmhouse itself. The term grange was also used in former times to designate the farming establishments attached to religious institutions.

GRANITE, an aggregate rock, the essential ingredients of which are feldspar, quartz, and mica, being the same as those of gneiss, from which granite differs chiefly in the arrangement of the three component parts. In granite these are mingled without order or regularity, which produces a granular structure, while that of gneiss is generally slaty.

"GRANITE is one of the most abundant rocks at or near the surface of the earth, it is likewise considered as the foundation rock of the globe, or that upon which all secondary rocks repose. In alpine situations it presents the appearance of having broken through the more superficial strata of the earth; the beds of other rocks in the vicinity rising towards it, at increasing angles of elevation as they approach it. It forms some of the most lofty of the mountain-chains of the eastern continent; and the central parts of the principal mountain-ranges of Scandinavia, the Alps, the Pyrenees, and the Carpathian mountains, are of this rock. No organic fossil remains have ever been found in granite, although it is sometimes found overlying strata containing such remains." (*Imperial Dictionary.*)

Of all materials for building, granite is the most durable, as shown by many of the ancient Egyptian monuments. By the Egyptians and other very ancient nations it was more particularly applied, together with sienite, for the purposes of architecture and statuary, and many very interesting monuments of their skill and patience are still existing in the collections of antiquities. As instances of the extreme durability of granite, we may mention, that the obelisk in the place of Saint Jean de Lateran at Rome, which was quarried at Syene, under the reign of Zetus, king of Thebes, 1300 years before the Christian era; and the one in the place of Saint Pierre, also at Rome, consecrated to the sun by a son of Sesostris, have resisted the weather for full 3000 years.

The use of granite for architectural and economical purposes is perhaps nowhere more amply displayed than at St. Petersburg, where not only the imperial and other palaces, but even ordinary dwelling-houses, have their lower parts lined with slabs of granite. The left bank of the great Neva, from the Foundry to the Gulf of Cronstadt, and both banks of the Fontanka and of the Catharine canal, are lined by high walls constructed of such slabs of granite; as are many bridges over the Neva, balustrades, &c. The pillars, stairs, balconies, &c. in the palace of Cronstadt, are almost all of the finest kinds of granite. Those employed for ornamental architecture are cut and polished by lapidaries; but those intended for less delicate purposes, such as common slabs, steps, cylinders, troughs, &c. are worked by peasants, particularly by those of Olonesk. The government-towns, however, Moscow not excepted, are too distant from the chief granite mountains, to be enabled to make frequent use of that rock for the above purposes.

Mr. Brand has divided the different granites used in the arts after their predominant colours; the following are the principal varieties, in which, however, the black-and-white kind is not included, one of its ingredients being hornblende, which assigns it a place among the sienites.

GRANITE, *Gray, of Chessi,* in the department of the Rhine, consists of white quartz and black mica, with large crystals of rose-coloured feldspar. The columns of the Eglise d'Enée (ancient temple of Augustus) at Lyons, are of this kind of granite, which has also been worked by the Romans.

GRANITE, *Gray, of Thain,* consists of gray quartz, black mica, and white feldspar crystals, which are sometimes from two to three inches long. The quarries of this granite are on the road from Lyons to Valence, on the right bank of the Rhône. It is very well adapted for the construction of large monuments. The granite of St. Peray, not far from Thain, is exactly like this, except that its feldspar crystals are of a rose-colour.

GRANITE, *Gray, of Lavezzi,* a small island near Bonifacio, south of Corsica, in the straits which separate that island from Sardinia, is composed chiefly of small irregular crystals of feldspar, mixed with a little black mica, besides which it contains also feldspar crystals, of a milk-white colour. In the quarry of that island a large unfinished column is to be seen, which had been relinquished by the Roman workmen.

GRANITE, *Gray, of Elba.*—Its grain is pretty uniform; its colour sometimes approaches to light violet. There are four columns of this variety to be seen in the Musée Napoleon: they were taken out of the church which contained the tomb of Charlemagne, at Aix-la-Chapelle.

They gray granites are much more common than the green or greenish, of which the following deserve to be mentioned.

GRANITE, *Antique green.*—Its predominant ingredient is white quartz, with here and there some light green feldspar. There is a column of it in the Villa Pamfili, near Rome.

GRANITE, *fine-grained antique.*—(Basalte verd oriental.) The component parts of this sort are so minute and intimately blended, that they can scarcely be distinguished by the naked eye. Its colour approaches to deep olive. It is very hard and takes a fine polish. The Egyptians have much employed it for the construction of monuments; and several statues of it may be seen in the Capitol and the Villa Albani. There is another variety with white spots, known at Rome under the name of *Basalto Orientale pidochioso;* but it is very rare, for there are but two columns of it in existence, namely, in the church of St. Pudentiana at Rome. Some varieties bearing that name are silenite.

GRANITE *of St. Christophe:* composed of violet quartz, white feldspar, and green mica. This magnificent rock is found at Oisans, in the department of the Isère.

GRANITE, *Corsican, orbicular.*—This beautiful rock (which probably belongs to the sienite formation) was discovered by M. Barral, in the island from which it derives its name. Its composition is very extraordinary; it has a basis of ordinary gray granite, which, however, in most parts exhibits a considerable portion of hornblende. But what more particularly characterizes it, is a number of balls, of from one to two inches in diameter, each composed of several concentric and perfectly parallel layers, the outermost of which, generally white, opaque, and two or three lines thick, is composed of quartz and feldspar, blended in various proportions, and exhibiting a radiated appearance, rather converging towards the centre of the ball. The second layer, which is of a greenish black colour, and about one line thick, is composed of fine laminar hornblende; and this is succeeded by a white and usually translucid quartz layer, of about four or five lines in thickness, inclusive of two or three very thin layers of hornblende, that are commonly seen within the substance of this third principal layer. Each of these layers is generally of equal thickness in the whole of its circumference. These three parts may be considered as the coating: the interior of each ball is less defined than the surrounding layers, and consists of a blackish and a whitish substance, the former surrounded by, and passing into the latter, the centre of which is usually a dark gray spot.

The quarry of this rock is unknown, a single block only having been found in the gulf of Valinco, in Corsica: its weight was about 80lb., but it was soon broken into small fragments, which are now distributed among collectors. There is a beautiful vase of it, one foot six inches high, in the cabinet of M. Dedrée. The granite of Corsica is figured by M. Faujas de St. Fond, in his *Essai de Géologie,* and in Mr. Sowerby's *Exotic Mineralogy.*

Among the red granites, we have what is called *red oriental granite*, which usually contains hornblende, often in large separate patches.

GRANITE, *Red, of Ingria.*—"This granite," says M. Patrin, "is distinguished from others in this, that the feldspar, instead of being in grains, or parallelopiped crystals, as in most other granites, constantly appears in the shape of round or oval pieces, of from half an inch to two inches in diameter. This granite takes a very fine polish, and in this state exhibits the feldspar in the shape of white, round, or oval (*chatoyant*) spots, in a reddish ground. The rock which serves as a pedestal of the equestrian statue of Peter the Great, at St. Petersburg, is of this granite: the block was originally 32 feet long, 21 feet thick, and 17 feet wide; but, in order to give it its present shape, imitative of a picturesque natural rock, it has been much diminished in size. This block was disengaged from a swamp, about forty versts from Petersburg: its weight was calculated to be above three millions of pounds." We have seen several fragments that were detached from the very block forming the pedestal of the statue; but in none of them did we observe the form ascribed by Patrin to the feldspar.

The public summer promenade-garden at Petersburg is decorated with a superb colonnade of this granite: the columns, which are sixty in number, are of the Tuscan order; their shafts, made of one piece, are about 20 feet high, and three feet in diameter. The island, called Kotlin-Ostrow, on which is the fortress of Cronstadt, is covered with blocks of this granite, the feldspar of which is sometimes of the kind called Labrador-stone.

GRANITE, *Red, of the Vosges Mountains.*—This granite is composed of large laminæ of rose-coloured feldspar, gray grains of quartz, and small scales of mica. It has so strong a resemblance to the Egyptian red granite, that it is difficult to distinguish them. Its quarries are on the heights of Montaujeu, near the Papean mountains, in the Vosges.

GRANITE, *Violet, of Elba.*—The feldspar of this variety is in large violet crystals. The pedestal of the equestrian statue, in the Piazza della Santissima Annonziata at Florence, is made of it, as are also the *sodes* in the chapel of St. Laurence in the same town.

GRANITE, *Rose-coloured of Beveno.*—This beautiful granite consists of flesh-coloured feldspar, white quartz, and some grains of black mica. Considerable quarries of it are found on the borders of the Lago Maggiore, which are worked without intermission, for supplying Milan, and the whole of the neighbouring country, with this granite. It takes a very fine polish: here and there it exhibits ribands, or zones, of a gray colour, which are composed of the same ingredients as the rest of the mass, but reduced into very minute particles. Many columns, porticos, &c. are seen of it at Milan.

The name of *Graphic granite* is given to those kinds in which the feldspar forms large concretions, intermixed with gray quartz crystals, exhibiting, when cut transversely, angular figures, mostly shaped like a 7; while others are less regular, and bear a distant resemblance to rude alphabetical writing. They are not considered to be genuine granite by some mineralogists.

GRANITE, *Graphic, of Portsoy.*—The feldspar is of various tints of pale flesh-red; the quartz dark, but transparent, with now and then some small particles of mica. This rock is minutely described by Dr. Hutton.

GRANITE, *Graphic, of Siberia.*—Its feldspar is of a yellowish white, or reddish colour; the quartz, exhibiting figures similar to those of the quartz in the preceding sort, is of the variety called *smoky topaz.* Mica occurs in it in small nests, and black shorl in acicular crystals.

GRANITE, *Graphic, of Autun.*—Of a pale rose-colour; quartz crystals gray, very numerous; found in the neighbourhood of Autun, department of Saône and Loire, particularly at Marmagne. This, in Mr. Brand's opinion, is the most beautiful of all granites. Another variety of this stone is found at the same place: its feldspar is white; the quartz gray, in small crystals; it is susceptible of a very fine polish.

GRANITE, *Graphic, of Corsica.*—Likewise of a rose-colour; but generally paler than that of Autun, from which it is also distinguishable by its quartz crystals being larger, and at greater distance from each other. It contains some thinly disseminated bronze-coloured mica, and takes a fine polish.

GRATICULATION, a term used by some writers for dividing a drawing into compartments of squares, in order to be reduced.

GRAVITY, *Table of Specific, See* SPECIFIC GRAVITY.

GREAT CIRCLE OF A SPHERE, a circle passing through the centre, which is one of the greatest.

GREAT STAIRCASE, *See* GRAND STAIRCASE.

GREEK ARCHITECTURE, such as was practised by the Greeks. For information on this general subject we must refer to the description of each order given under their several titles, where will also be found some account of their origin and progress. *See* below, GREEK ORDERS; also ARCHITECTURE, ROMAN ARCHITECTURE, &c.

GREEK CROSS. *See* CROSS.

GREEK MASONRY, the manner of bonding walls, as used by the Greeks. *See* MASONRY.

GREEK MOULDINGS, *See* MOULDINGS.

GREEK ŒCUS. *See* ŒCUS.

GREEK ORDERS, are the Doric, Ionic, and Corinthian orders. *See* DORIC, IONIC, and CORINTHIAN; also ORDERS, and ARCHITECTURE.

GREEK ORNAMENTS. *See* ORNAMENTS.

GREENING, in plumbery, the rubbing of a new sheet of lead with any green vegetable, where it is to be soldered, in order to prevent the solder from adhering except at the places where it is scraped off.

GREENHOUSE, a house of shelter in a garden, contrived for preserving the more tender and curious exotic plants.

Structures of this kind were formerly erected with slated roofs, like dwelling-houses, and with large upright windows in front, divided and supported by pillars; examples of which may yet be seen in several of the royal gardens about London, and also in different parts of the country. It was soon found that handsome specimens of plants could not be grown in houses of this description; and the only purpose to which they are now applied, is the growing of orange or lemon-trees, and protecting other plants in winter.

GREENHOUSES, as now built, serve not only as conservatories, but likewise as ornaments of gardens; being usually large and beautiful structures, sometimes in the form of galleries, wherein the plants are handsomely ranged in cases. *See* CONSERVATORY.

The greenhouse is a sort of building designed for the purpose of preserving various kinds of exotic shrubs, &c., through the winter season, and for growing and protecting those kinds of plants which are too tender to live in the open air. It is fronted and covered with glazed frames, but the aid of artificial heat is not necessary except in intensely cold weather. It is advisable, however, in constructing such houses, to erect flues to use occasionally, which may prove serviceable, not only in severe frosts, but also in moist, foggy weather, when a moderate fire will now and then dry up the damps, which would otherwise prove pernicious to many of the tender kinds of plants.

It differs from the conservatory chiefly in this circumstance,

that the plants, trees, or shrubs, are in pots or tubs, and placed upon stands, frames, or stages, during the winter, to be removed to proper situations in the open air, during the hot summer season; while in that, there are beds, borders, and clumps, laid out in the ground-plan, and made up with the best earthy materials, to the depth of three or four feet, in which the shrubs, trees, &c. are regularly planted; the whole of the roof being removed during the summer to admit fresh air, and replaced on the approach of the autumn, to remain until the following summer.

Greenhouses should stand in the pleasure-ground, near the house, if possible, upon a somewhat elevated spot, full to the south, and where the sun has access from its rising to its setting. These buildings are generally of brick or stone, having the fronts and tops almost wholly of glass-work; and ranging lengthwise east and west. They are generally constructed upon some ornamental plan. As to the general dimensions, in respect to length, width, and height, they may be from 10 to 50 feet, or more, in length, according to the number of plants to be contained; and in width, from 10 or 15 feet to 20 feet; but, for middling houses, 15 or 18 feet is a sufficient width; and in height in the clear, nearly in proportion to the width.

The walls on the backs and ends, particularly the former, should be carried up two bricks thick; and if more than 15 feet high, two bricks and a half thick; at one end of the back wall, on the outside, a furnace may be erected for burning fires occasionally, communicating with flues within, ranging in two or three returns along the back wall, having one flue running along the front and end walls, raised wholly above the floor of the house.

The fronts of the buildings should have as much glass as possible, and wide glass doors should be made in the middle, both for ornament and entrance, and for moving in and out the plants. It would also be convenient to have a smaller entrance door at one end; the width of the windows for the glass sashes may be five or six feet: and the piers between the sashes may be either of timber, six, eight, or ten inches wide, according to their height, or if of brick or stone work, two feet wide at least, sloping both sides of each pier inward, that by taking off the angles, a free admission may be given to the rays of the sun. For the same reason, the bottoms of the sashes should reach within a foot of the floor of the house, and their tops almost as high as the roof; and if brick or stone piers two feet wide, shutters may be hung on the inside, to fall back against each pier. The roof may be either wholly or only half glass-work, next the front; the other half slated, especially if the upright or front piers are of timber; and the shutters to cover the top glasses may be so contrived as to slide under the slated roof: where the piers are of brick or stone, it is common to have the roof entirely slated or tiled; but slating is the most ornamental for a half or whole roof; and the ceiling within should be white; which, as well as the whole inside wall, must be well plastered and white-washed, so as to render it clean and neat.

But in greenhouses of modern construction, in order to have as much glass as possible in front, the piers between the sashes are commonly of timber only, from six to eight or ten inches thick, according to the height, so as to admit as great a portion of light and heat of the sun as possible, and the roofs are wholly of glazed frame-work.

The greenhouses for large collections of plants have sometimes two wings of smaller dimensions, added to the main building, at each end, in a right line, separated sometimes from it by a glass partition, with sliding sashes for communication, and the front almost wholly of glass-work, and half or whole glass roofs. Thus, by these additional wings, the houses consist of three divisions, whereby the different qualities and temperatures of the various plants can be more eligibly suited. The middle, or main division, may be for all the principal and more hardy, woody, or shrubby kinds, which require protection only from frost; one of the wings appropriated for the succulent tribe, and the other to the more tender kinds, that require occasionally heat in winter, but which can live without the heat of a stove or hot-house.

On whatever plans greenhouses are constructed, the whole of the inside walls should be neatly finished off with plaster and whitewash, and the wood-work painted white; the bottom being paved with large square paving tiles, or some similar material.

In the greenhouse there should be stands, frames, or tressels, which may be moved in and out, upon which rows of planks may be fixed, so as to place the pots or tubs of plants in regular rows, one above another; by which their heads may be so situated as not to interfere with each other. The lowest rows of plants next the windows should be placed about four feet from them, that there may be a convenient breadth left to walk in front; and the rows of plants should rise gradually from the first, in such a manner, that the heads of the second row may be entirely advanced above the first, the stems only being hid; and at the back of the house a space allowed of at least five feet, for the conveniency of watering the plants, and to admit a current of air round them, that the damps occasioned by their perspiration may be the better dissipated; when this is not done, the damps, pent in too closely, often occasion a mouldiness upon the tender shoots and leaves, and, when the house is close shut up, this stagnating rancid vapour is often very destructive; for which reason the plants should never be crowded too close to each other, nor should succulent plants ever be placed among them.

GRIFFIN, or GRIFFON, (from the Greek γρυψ,) a fabulous creature, usually supposed to have the head and wings of an eagle, with the body, legs, and tail of a lion; but sometimes with the head of the latter, and the horns and beard of a goat, as in the Ionian antiquities. The ancients adorned the statues and temples of their gods with symbols of their supposed influence. The griffin, which was particularly sacred to Apollo, and in fabulous antiquity believed to be ever watching the golden mines on the Scythian and Hyperborean mountains, is introduced as a guardian of the lyre, which belonged to him, as inventor of music. It has a lion's head, because Apollo, or the sun, is most powerful when in that sign of the zodiac. The Persians also had a statue of him, with the head of that animal.

GRILLAGE, in engineering, a term applied to a kind of frame-work, made something like a grating, of heavy pieces of timber laid lengthwise, and crossed by other pieces, notched down upon them. It is used to sustain foundations, and prevent their irregular settling, in soils of unequal firmness or solidity. This frame-work is firmly bedded, and the earth packed into the interstices between the timbers; a flooring of thick planks, termed a platform, is then laid on it, and on this the foundation-courses rest.

GRINDSTONE, a cylindrical stone, mounted on a spindle through the axis, and turned by a winch-handle, for grinding edge-tools.

GRINDING, the act of wearing off the redundant parts of a body, and forming it according to its destined surface.

GRIT-STONE, a stone consisting of particles of sand agglutinated together. Of this kind of stone there are many varieties, differing in the size of the particles of sand that compose them, the several properties of these sands, and their various degrees of compactness and agglutination.

Some of them are used for building, others for grinding, others for whetting sharp steel instruments, and others for filtering water. *See* STONE, and WHETSTONE.

GRIT-STONE, in mining, a hard granular or gritty stone, composed of grains of silex or quartz, cemented together, generally either by a silicious, an argillaceous, or a ferruginous cement. The first of these, or the silicious grit-stones, are alone fit to be used in repairing roads. The other sorts, in wet weather, soon become a heavy sandy mire upon the road; when the argillaceous parts are dissolved and washed away by the winter rains, this mire changes in summer to loose sand, rendering the roads almost intolerable. Most travellers will have observed this in the argillaceous grit-stone district about Ashby de la Zouch, in Leicestershire, and numerous other coal countries, and the ferruginous grit-stone district about Woburn, in Bedfordshire, and other places. The greater part of the numerous grit-stone rocks and beds of such stone in the coal-mines, are argillaceous, of a fine grit, with minute plates of mica, and are unfit for roads, until hardened by the action of fire; being still, however, very weak and improper materials for road-making, if better can be produced.

A large portion of the argillaceous grit-stones have but a slight disposition to perish or moulder when exposed, and can be used in walls and ordinary buildings; others will perish in a few years; and a large portion of what appears, when first dug, at proper distances below the surface, to be very hard grit-stone, will, after a very short time of exposure, fall to a loamy or clayey sand; such very perishable grit-stone strata are called, by the colliers, *stone-binds, gray-beds*, &c., except about Newcastle, where they are denominated *sand-stones.*

In some places, crystallized granular lime-stones occur, as in the yellow or magnesian lime-stone range, near Mansfield in Nottinghamshire, and such are sometimes, though improperly, called *grit-stones*, or *gritty lime-stones. See* SANDSTONE.

GROIN, in architecture, the hollow formed by the intersection of two or more simple vaults, crossing each other at the same height.

In the geometrical point of view, the centre of a groin is formed by the entire meeting of the surfaces of two or more cylindrits; that is, such, that every straight line around the whole circumference, on the surface of the one cylindrit, will meet every straight line around the circumference of the one adjoining.

Hence the sections parallel to the axes of all the cylindrits which form the groin are in the plane of their springing; otherwise the surfaces could not meet each other entirely.

Hence, also, the axes of all the cylindrits are also in the same plane, and cut each other in the same point.

In the above definition of a groin, it must, however, be observed, that its surface is no portion of that of the solid which would be contained by the surfaces of the cylindrits and a plane passing through their axes, but only that part of the whole which is formed on the outside of the space which would be thus enclosed in the centre of the groin and form a polygonal dome. The surface of the groin is therefore equal to the whole of the cylindritic surfaces, deducting that of the dome.

The surface of any cylindrit is either that of a cylinder or cylindroid.

When the cylindrits which form the groin are all cylinders, the two vaults are of equal breadth.

In any simple vault of a groin, the planes which are tangents to the surfaces at the springing, have equal inclinations with each respective wall. When all the openings of a groin are equal, the groin is termed an *equilateral.*

The branches of a groin are each of the two opposite parts of each simple vault.

The invention of groins must have been subsequent to that of simple vaulting, and probably originated from arched passages, when it was necessary to occupy the whole height. At what time they were first introduced in architecture, is uncertain; the remains of antiquity show that they are of very remote date, which, however, cannot be traced beyond the times of Roman power and grandeur. Use or necessity was, without doubt, the occasion of their invention, but in process of time they were used as ornaments, and became fashionable at the decline of the Roman empire; they are to be found in the amphitheatre at Rome, formed at the intersections of the radiating and elliptic passages. In the temple of Peace, and baths of Diolcetian, at the same place, instead of massive piers, they are supported upon columns, the most feeble of all supports, and which would be incapable of resisting the lateral pressure of the arches, were it not for the auxiliary support of the walls immediately behind them, at the sides and angles of the building, which act as buttresses.

Groins continued to be used after the dissolution of the Roman empire, in ecclesiastical structures; and wherever grandeur or decoration was required, they were never omitted; they became the most principal ornament of the time, and formed the most conspicuous features in the edifices in which they were employed: at first they were used in the same manner as by the Romans, but in after-times the groins were supported upon ribs, which sprung from cylindrical or polygonal pillars, with capitals of the same form; this produced a necessary change in the figure of the vaulting, as the bottoms of the ribs rose from the circumference of a circle, instead of the angles of a square, with its sides parallel to the walls; and as the spaces between and over the ribs were vaulted in a twisted or winding surface, so as to coincide in every part with a straight line level between the ribs, the angles of the groined surface were thus very obtuse at the bottom, but diminished continually upwards, and ended in a right angle at the summit of the ceiling. Afterwards, when the pillars were formed upon a square plan, the sides of which were obliquely disposed with regard to the sides of the building, and decorated with vertical mouldings, or small attached columns, and the number of ribs increased, the first idea of fan-work would be presented at the springing of the ribs; but in this the architects would soon perceive an incongruity of form in the surface, as it approached the summit of the vaulting; the ribs would be formed all of equal radii, and disposed around, to support a concavity, which might be generated by revolving a curve round an axis which was in the centre of the pillars; and being accustomed to groins meeting in lines crossing each other, it was natural to suppose they would at first permit the ribs to run out and meet each other, which would then be of unequal lengths. If the difference between the openings was not very great, the intersection thus formed by the meeting of the opposite sides of the vaulting would not differ materially from straight lines, but would not be parallel to the horizon, as they would run upwards towards the centre of the groin; but this would depend on the angle formed by two opposite ribs in the same plane. Thus, if the tangents formed at the vertex of the opposite curves contained an angle of 120 degrees, the apex line on the ceiling would form a curve in receding from the vertical angle of the said ribs, of a very decided convexity; but in going progressively forward, the curvature would change into a concavity, and then would

begin again to descend. The idea of intersecting the ribs thus disposed in vertical planes around a common axis, by circular horizontal ribs, was natural; and thus again would generate another idea of supporting the upper ends of the ribs, by a circular ring concentric with the axis of the pillar, and this being done from four pillars, would leave a space enclosed by four convex arcs of circles: nothing farther was required to complete this system of vaulting than to fill up the space, and the whole would be keyed together. In this manner, by slow and imperceptible changes, a species of vaulting was invented, very different from that of the Greeks and Romans. Instead of closing the space, if we suppose another ring, forming a complete circumference, to be built interiorly to touch the former arcs, and the four triangular curved spaces closed and wedged together with masonry, the whole will stand equally firm as if the middle had been solid, and thus an aperture for light will be formed the same as in dome-vaulting. This species of vaulting has also another property, that it can be carried up from a square plan with less hazard than the common mode of groining.

In warehouses which are loaded with the greatest weights, and where the walls are placed at a remote distance, it becomes necessary to introduce many supports to the floors: these, if constructed of timber, being liable to accidents from fire, and to rot, are consequently exposed to sudden danger; to prevent which, every precaution should be taken, at least as far as may appear to be warrantable from the profits to arise from the articles to be deposited. This will be fully accomplished by the introduction of groins, which not only answer the same purpose as the flooring of timber-work with its wooden supporters, but are more durable, and proof against fire and rot. Though groins are only employed in the lower stories of buildings, on account of the great expense and loss of space which would be occasioned by the requisite thickness of the walling; yet they may at all times be used in cellars and ground stories, without much additional labour or expenditure of materials.

It having been found that brick groins, rising from rectangular piers, are inadequate to the weight they have to support, and are incommodious to the turning of goods round the corners of the piers, it will be found convenient to employ octagonal piers, and to cut off the square angles of the groin, equal to the breadth of the side of the piers. This mode of construction is decidedly preferable to that in which square piers are used; for the angles of the groins, built in the common way, as they form a right angle, are hardly capable of sustaining themselves, much less the load required to be supported, owing to the bricks being so much cut away at the angles, in order to fit them thereto and to each other, so that they have little or no lap. This scheme should certainly be carried into practice, wherever groins are applied to such uses.

In the construction of edifices for dwelling, they ought always to be employed in cellars, and other damp situations, particularly where there are paved apartments above.

Groins for use only, may be indifferently constructed of brick or stone, as one or other material may be most easily procured.

If employed by way of proportion or decoration, their beauty depends on the generating figures of the sides, the regularity of the surface, and the acuteness or sharpness of the angles, which should not therefore be obtunded. In the best buildings, where durability and elegance are equally required, they may be constructed of wrought stone; and where elegance is wanted at a small expense, of plaster, supported by timber-work.

Groins are consequently constructed in two different ways, according as they are built of stone or brick, or formed of timber-work, lathed and plastered. In the former case, a timber centering is made to form the concavity, and to support the groin during its erection. The centering consists of several ribs, disposed at three or four feet distance, made to the size of the vault which has the greatest opening: The extremities of these ribs rest on beams supported by standards, and are boarded over without any regard to the transverse openings, which are afterwards formed by another set of ribs adapted thereto, and then boarded so as to meet the boarding of the first vault, which if of considerable breadth, must have short ribs fixed upon its surface, in order to shorten the bearing of the boarding of the transverse openings; and thus the centering will be completed. It is obvious, that in forming the ribs for each vault, the outer curve must be the arc of a circle or ellipsis within the curve of the vault, and distanced from it towards the axis equal to the thickness of the boarding. In making the groined centre, it will be necessary to find the place of the angles on the boarding of the large vault, in order to ascertain the place of the ribs and boarding of the transverse vault; this may be done by three different methods. First, let two straight edges be placed vertically at the angles, and a third straight edge, or an extended line, be made to touch the surface of the boarding, and marked at all the points of contact, keeping the latter straight edge or line always upon the edges of the two vertical straight edges.

The defect of this method is, that the place of the angles at the bottom can never be found, since it would require the cross straight edge or line to be of infinite length, and the vertical ones of infinite height. A more eligible method, therefore, where there is room, is, secondly, to fix two ribs in the transverse part, and direct a level straight edge upon their edges, so that the end may come in contact with the boards, and mark the boarding in this place; find a sufficient number of points for the purpose, in the same manner, and draw curves through the points, which will give the curves for fixing the end of the filling-in ribs, otherwise called *jack ribs.*

In constructing groins to be finished with plaster, the angle-ribs must be first fixed, then straight longitudinal pieces parallel to the axis of the groin fixed, either flush with the under sides of the angle-ribs, or their under sides a little below those of the angle-ribs, so as to admit of their being nailed together; this is the most eligible method of constructing plaster groins.

There is another mode, by forming curved ribs, in planes perpendicular to the axis of each simple vault: but here, as the curve of these ribs must be the same as that of the cylindrit of each simple vault, the waste of timber will be very great; though not if the ribs are constructed in straight pieces. Whatever mode is adopted in the formation of plaster groins, the under sides of the ribs must always range in the intended surface of each simple vault. These constructions will be more clearly understood in the following explanations.

Plate 1. (Centering for Groins,) *Figure* 1, No. 1. A plan of the widest opening of the groin, first boarded the whole length without interruption; then the cross vaults are boarded; the two cross openings upon the left hand appear as finished, ready to receive the masonry or brickwork, while that on the right exhibits the ribs without the boarding.

No. 2. The elevation of the widest aperture, showing the edges of the ribs of the transverse openings fixed upon the surface of the boarding of the longitudinal opening; this also shows the height of the jack-ribs, which will give their length also.

No. 3. Shows the elevation of the transverse apertures, as completely finished.

Problem I.—*Given one of the ribs of the transverse ranges, to find the body-range.*

Suppose the given rib to be a semi-circle, or a semi-ellipsis, describe a semi-ellipsis, the length of which is that of the body-range, and the semi-conjugate axis the height of the given rib, which is that of the groin; and the semi-ellipsis thus described will be the contour of the ribs which are to form the body-range.

In the same manner, if a rib of the body-range be given, that of the transverse openings may be found.

But if the given rib be any other curve than that of a semi-circle or semi-ellipsis, lay down the curve of half the given rib upon any straight line, as a base; from the point where the curve intersects the base, draw another straight line at a right angle therewith: upon this line set the extent of half the width of the range from the angular point: complete the rectangle, of which these two straight lines are adjoining sides; draw that diagonal of the rectangle which meets the curve given; take any number of points in the given curve, draw ordinates perpendicular to the base to intersect them; from these points draw lines parallel to the other two sides of the rectangle, to meet the diagonal; from the points of division, draw straight lines parallel to the base of the given rib, to meet the side of the rectangle, which joins the curve of the given rib; from these points raise perpendiculars; transfer the ordinates of the given rib upon the perpendiculars; and the curve drawn through the extremities of these perpendiculars will be that of the rib required.

Figure 1, No. 4, $f\,q\,k\,g\,f$ is the given rib, $g\,f$ its base, equal to half the width, $c\,d$, No. 3, of the transverse openings; $f\,t\,i\,e\,f$ is the rib found from the given rib $f\,q\,k\,g\,f$, and $f\,e$ its base, equal to half the width, $a\,b$, of the body-range.

Figure 1, No. 5. Shows the method of finding the mould for drawing the angles for placing the jack-ribs. The operation is thus performed:

Figure 1, No. 5. Upon any straight line, $m\,l$, transfer the arc $f\,t\,i$, No. 4, stretched out with all its parts from l to m; from the points thus transferred, erect perpendiculars, and transfer $e\,h$, No. 4, to the middle perpendicular, $n\,o$, No. 5; then the remaining parallels of $e\,h$ of the triangle $e\,h\,f$, No. 4, respectively to the parallels of $n\,o$, No. 5, on each side of it; and through the remote extremities of these perpendiculars, draw a curve each way from the point o; and thus two equal curves will be formed. But lest the reader should not be able to follow a general description, the following shows not only how any particular point may be found in the required rib, but also how any point may be found in the covering.

First: *To find a point in the required rib.*

Figure 1, No. 4. Take any point, q, in the given rib; draw $q\,p$ perpendicular to $g\,f$ the base; draw $p\,r$ parallel to $f\,e$, cutting $f\,h$ at r; draw $r\,s$ parallel to $g\,f$, cutting $f\,e$ at s; draw $s\,t$ perpendicular to $f\,e$; make $s\,t$ equal to $p\,q$, and t is a point in the curve. In like manner, as many points may be found as required.

Now let it be required to find the point u, No. 5. Transfer the arc $i\,t$, No. 4, upon the straight line $m\,l$, No. 5, from n to u; draw $u\,v$ perpendicular to $m\,l$; make $u\,v$ equal to $s\,r$, and v is a point in the curve. The trilinear area $m\,o\,l$ is the envelope of the portion of the groined surface represented by either of the two triangles of the plan of the groin, which have the width of the body-range for the base; $m\,o$ is the edge of a mould by which the angle of the groin, or the cylindritic lines, are found; the point m is laid to the bottom, and the mould bent upon the surface, so that the point o may be in the summit, and the convex side of the mould towards a vertical section passing through the point from which the bottom of the mould rises.

Figure 1, No. 6. Shows the envelope corresponding to either of the two triangular parts of the plan of the transverse parts, and is found in the same manner as No. 5. This shows the mould for cutting the boarding, by laying it out to the full breadth upon a plane, and drawing the ends of the boards by the curved edge of the mould, so as to fit against the boarding of the body-range.

Figure 2. Shows the construction of a groin upon an inclined plane, the widest opening, or body-range, having its ascent or descent in the direction of the inclination of the plane; the transverse ranges are therefore level. The ribs in both directions are set in vertical planes. The rib for the body-range is a semi-ellipsis; those of the sides will also be semi-ellipses, but will not have their axes in a vertical and horizontal position. The elevation of the transverse openings is shown at No. 2, and that of the body-range at the lower end. Each elevation exhibits the construction of the centre, a section of the boarding, and the manner of placing the jack-ribs.

No. 3. Is a section of the body-range at right angles to the plane of its inclination.

No. 4. Shows the form of the moulds for drawing the angles, in order to place the jack-ribs. The construction is thus: Divide the half, $d\,f$, of the curve $d\,e$, No. 3, into any number of equal parts; from the points of division draw lines parallel to the axis of the body-range, cutting the diagonal A L; from the points of intersection draw lines parallel to the sides of the transverse opening, and continue them on the other side of the inclination, $g\,h$, of the elevation of the said openings; from $g\,h$, as a base, make the heights of the several lines thus continued equal to the corresponding heights of the elevation of the body-range, and a curve drawn through all the extremities will give the form of the ribs, $i\,p\,k$, for the transverse openings. From the summit of the centre thus constructed, draw the line $v\,w$ at right angles to the inclination $g\,h$; extend the arc $d\,f$, No. 3, with its divisions, to $v\,w$, No. 4; through all the points of division in $v\,w$ draw lines at right angles thereto; from all the points found in the curve of the rib $i\,p\,k$, No. 2, draw lines parallel to $i\,h$, cutting the respective lines perpendicular to $v\,w$; and a curve drawn on each side of $v\,w$ will give the angle of the groin.

Groin Ceiling, a cradling constructed of ribs, lathed and plastered. It differs in its construction from groin centering, as the former requires angle-ribs. There are two different methods of constructing groin-ceilings; one by ribs fixed vertically and perpendicularly to the sides of each branch; the other by angle-ribs and ceiling-joists, or straight pieces of timber, running parallel to the axis of each branch, fixed to the angle-ribs, and to other intermediate ribs, in vertical planes, at right angles to the sides of each of the branches, and placed upon opposite piers, to shorten the bearing, in order to make less scantlings for the ceiling-joists, and thereby save timber. But in whatever mode the groined-ceiling is constructed, the surface must finish in the same manner. It is evident, however, that the latter method by ceiling-joists will require much less timber and workmanship than the former, where so much stuff is cut to waste, and so much time employed in making the angle-ribs.

Figure 1. The cradling of a groin ceiling, constructed with ceiling-joists. Stout ribs are thrown across the angles and between the opposite piers; the ceiling-joist being put on below and spiked upwards. In this, the rib, $a\,l\,b\,c$, of a transverse range is given, to find the others. Take any number of points in the half arc $a\,l\,b$; draw lines parallel to $g\,i$, the base of the rib of the body-range, to cut the diagonal $d\,f$; from the points thus obtained in $d\,f$, draw lines at right angles to $d\,f$, and make the corresponding perpendiculars equal to

those of the given arc $a\ l\ b$; then construct the other half by reversion, and it will form the whole angle-rib.

To obtain the rib of the body-range from the points of section in the base line $d\ f$, draw lines parallel to $a\ c$, to cut $g\ i$, and produce them on the other side of $g\ i$; from the points thus obtained in $g\ i$, transfer the corresponding heights of the ordinates of the given rib upon the perpendiculars as ordinates, then construct the ordinates of the other half by reversion, which will give the curve of the ribs of the larger branch.

Figure 2. The cradling of a groin-ceiling, constructed entirely of ribs. The section of the ceiling of the transverse ranges is that of a semi-circle; consequently, the angle-ribs, and those of the body-range, are semi-ellipses, the width of the body-range being greater than those of the transverse branches. The description of the curves of the ribs will be found under the article Ellipsis, *Method* III. *Figure* 3.

The ribs must be bevelled each way, so as to range with either branch of the groin. This is best done by getting them in two thicknesses, then each half of each thickness must range the contrary way, one half with the ceiling of the largest branch, and the other half with the ceiling of the lesser branch, in the same groin; the branches being supposed on the same side of the diagonal: so that when the two parts are put together to form the rib completely, the bevelling of the one half of one thickness and that of half of the other, will range with the surface of the ceiling of one branch, and the contrary edges with the surface of the ceiling of the other branch. In ranging the ribs, each thickness is cut out by the mould: then, in order to range the half of each thickness, the mould must be shifted, so that the upper point of the curved edge will slide in a line parallel to the base, while its lower point will slide upon the base line to the distance required at the bottom: this is represented on the lower end of the principal branch.

Figure 3. A groin in which the principal branch is inclined: $i\ k\ l$ is the given curve of the rib; $a\ b$ the line of elevation of the spring of the arches. Draw the diagonal $p\ o$, and $o\ s$ perpendicular to it; join $o\ n$, which produce to cut $a\ b$ at r; make $o\ s$ equal $q\ r$; produce $o\ p$ to meet $i\ l$ at a, and join $s\ a$ (*the reader must however observe, that the engraver has joined* s p *instead of* s a, *and has not produced* o p, *as here stated, and as it was in the drawing*). Bisect $i\ l$ at y; through y draw $k\ v$ parallel to $m\ o$ or $p\ n$, meeting the curve in k, and $o p$ at v; draw $v\ u$ perpendicular to $o\ p$, cutting $s\ a$ at t; make $t\ u$ equal to $y\ k$; draw v x parallel to $i\ l$, cutting $a\ b$ at w; make w x equal to $y\ k$; then $p\ s$ will be a diameter, and $t\ u$ the semi-conjugate of the ellipsis, which forms the curve of the angle-rib: also $w\ r$ and w x are the semi-conjugate diameters of the curve of the ribs for the transverse branches, and the curves may be described as in *Method* V. *Problem* I. of the article Ellipsis. Or, the two axes may be found as in *Problem* II. of the same article, and the curves described according to *Method* III. *Problem* I.; or the curve may be drawn by ordinates as here exhibited. The cradling is shown at the lower end.

Figure 4. Shows the construction of ribs for the arches of apertures cut under the pitch of a large vault at right angles to the wall. Apertures of this description are called *lunettes.*

Let A $z\ e\ m\ p$ D be the curve of the section of the principal vault; it is required to construct the ribs of a lunette of a given height.

Produce the base A D to k, and the side g D to l; let $f\ g$ be the breadth of the aperture; bisect $f\ g$ in i; draw $i\ h$ perpendicular to $f\ g$, which assume equal to the intended height of the lunette; draw $h\ k$ parallel to g D, cutting D k at k; make D l equal to D k; draw $l\ m$ parallel to D A, cutting the curve of the principal vault in m; draw M o parallel to D g, cutting $h\ i$ produced to o; join $o\ f$ and $o\ g$; assume any number of points in the part $m\ d$ of the curve D $m\ e$ A; from the assumed points draw lines parallel to $m\ o$, cutting $o\ g$; from the points of division draw lines perpendicular to $o\ g$; make the lengths of the several perpendiculars from the base equal to the corresponding ordinates contained between the base n D and the arc m D; then a curve being drawn through the remote extremities of the perpendiculars not in $o\ g$, will give the curve of the angle-rib. Again, from the intersections in $o\ f$ and $o\ g$, draw lines perpendicular to $f g$, and produce them on the other side of $f\ g$; make the heights of the perpendiculars equal to the corresponding heights of the ordinates belonging to the curve D m, of the given rib on each side of the middle line $i\ h$; then a curve being drawn through all the extremities of the perpendiculars not in $f\ g$, will give the curve of the ribs of the lunette.

On the left-hand side is shown another method of tracing the curves of the angular rib, and of ribs forming the sides of the lunette. The cradling is shown below the lower end of the plan.

Groin, sometimes spelt Groyne, a kind of jetty built across the beach at right angles to the line of the shore from high to low-water mark. Groins are used particularly on the southern and south-western coast of England, to retain the shingle already accumulated, to recover it when lost, or to accumulate more at any particular point; also to break and check the action of the waves. The following description of a groin is taken from Mr. Weale's very useful little work, 'A Dictionary of Terms of Art:'—

"The component parts of a groin are piles, planking, land-ties, land-tie bars, blocks, tail-piles, and keys and screw-bolts. The length of a groin depends on the extent, and the requisite strength of its component parts on the nature of the beach on which it is to be constructed.

"Those at Eastbourne, on the coast of Sussex, of which the following is more particularly a description, are from 150 to 250 feet in length, and the beach at that place being very rough, consisting of coarse heavy shingle and large boulders, they require to be composed of proportionably strong materials to resist its force.

"The piles are from 12 to 25 feet long, and 8 by 6½ inches scantling, shod with iron. The planking is in length of 8, 12, and 16 feet, 2½ inches thick, and with parallel edges. The land-ties are of rough timber from 20 to 25 feet long, and large enough at the butt-end to receive the bars. The land-tie bars are 13 feet 6 inches long, and 12 by 5 inches scantling. The land-tie-bar blocks are about 2 feet long, and of the same scantling as the piles. The land-tie tail-keys are about 2 feet 6 inches long, and 6 by 2½ inches scantling. The above materials are of oak or beech. The screw-bolts are of inch round iron, 2 feet 9½ inches, and 2 feet 1½ inch long, in equal proportions.

"The relative proportions of the component parts are, four piles, one land-tie with tail-piles and keys, one land-tie bar with two blocks, two long and two short bolts, about 180 square feet of planking, and about 140 six-inch spikes for every 16 feet in length; and the expense of a groin, constructed with materials of the above dimensions, may be calculated at about £30 for the same length.

"General rules observed in the construction.

"When the object, in constructing a groin, is to recover shingle, or accumulate more, the first pile is driven at the high-water mark of neap-tides, leaving its top level with that of spring-tides. The next is driven at the point on the sands, beyond the bottom of the shingle, to which the groin is to

extend, leaving about four feet of it out of the beach. The tops of these two piles may be taken for the general slope of the groin, unless the beach should be very steep, and much curved, in which case it becomes necessary to follow its curvature in some degree. From the high-water mark of neap-tides, the piles are carried back nearly level to that of spring-tides, and as much further as may be considered necessary. The piles are driven four feet asunder from centre to centre, and so as to admit the planking between them alternately, and they should be sunk about two-thirds of their length. The longest piles are placed between the high-water mark of neap-tides and the bottom of the shingle, particularly from 20 to 40 feet below the former point. The planking is, if possible, carried down to about two-thirds from the tops of the piles, and kept parallel with them. The land-ties are placed about one-third from the top of the planking (supposing the latter to commence from the tops of the piles,) and their tails are sunk to the level of the bottom of the planking or as nearly so as possible."

GROOVE, a channel cut in a piece of wood by taking away a rectangular prism, one of the sides of which is a portion of the side of the wood in which the excavation is made. A groove therefore forms two external, and two internal angles. It differs from the rebate thus: the rebate is formed by taking away a rectangular prism at the angle, and consequently the part taken away has two of its sides common to those of the piece, with one internal, and two external angles.

A groove is made in joinery by a plough, which is moveable so as to admit of the excavation being run at any distance from the arris.

Grooves are frequently used in order to insert a tongue in the joint of two pieces of wood, intended to be united. They are also used for inserting the panels in framed work, as in doors, shutters, partitions, &c.

In the present day, grooves are among the most fashionable ornaments; but there are few or no instances of their decorative use among the ancient Greeks and Romans.

GROTESQUE, that beautiful light style of ornament used by the ancient Romans, in the decoration of their palaces, baths, and villas. It is also to be seen in some of their amphitheatres, temples, and tombs, the greatest part of which being vaulted, and covered with ruins, have been dug up and cleared by the modern Italians, who for these reasons gave them the name of *grotte*, which is perhaps a corruption of the Latin *cryptæ*, a word borrowed from the Greeks, as the Romans did most of their terms in architecture: and hence the modern word *grotesque*, and the English word *grotto*, signifying a *cave*.

In the time of Raphael, Michael Angelo, Julio, Romano, Polidore, Giovanni d'Udine, Vasaro, Zuchero, and Algerdi, there is no doubt but there were much greater remains of the grotte than what are now to be seen, and in imitation of them were decorated the loggias of the Vatican, the villas of Madonna, Pamfili, Capraola, the old palace at Florence, and indeed whatever else is elegant or admirable in the finishing of modern Italy.

This classical style of ornament, by far the most perfect that has ever appeared for inside decorations, and which has stood the test for so many ages, like other works of genius, requires not only fancy and imagination in the composition, but taste and judgment in the application, and when these are happily combined, this gay and elegant mode is capable of inimitable beauties.

Vitruvius, with great reason, condemns an over licentiousness of this kind and blames the painters of his time for introducing monstrous extravagances. We do not mean to vindicate any thing that deserves such appellations; but surely in light and gay compositions, designed merely to amuse, it is not altogether necessary to exclude the whimsical.

Its origin is discernible in the Egyptian hieroglyphic writing, where the heads and limbs of men and beasts are attached to blocks of stone, to vases, or to foliage, &c., thereby characterizing the inclinations and the powers of the deity or person whose history they record, or whose peculiar transactions they are intended to preserve in the remembrance of future ages.

With the Egyptians it remained rude and unpolished; but when the Greeks adopted it, they made an ornamental use of it, and it became a medium to exhibit their general knowledge of nature. The taste with which they united in one form, not only parts of various animals, but objects so totally diverse in their nature and appearance, as the productions of the animal and vegetable kingdoms, is in the highest degree delightful to contemplate. The formation of chimerical beings, as the dragon, the sphinx, the griffin, &c., owe their origin to this taste; which received much of its force and interest in heathen days, from the mythological enigmas couched under these compound forms. Such is the character of that ornament so common on Egyptian structures, the winged serpent surrounding an egg. Now that these mysterious emblematic meanings are disregarded, and no longer treated with reverence, grotesque painting and sculpture are continued in use merely because the forms they produce are pleasing to the eye; and although the understanding is insulted by them, such is the power of the beauty of form, that we are gratified by it, in spite of our reason.

Those who wish to make themselves acquainted with it, will find the best exemplars on ancient Greek sarcophagi, altars, vases, friezes, &c., of which Piranesi and Rocchegiani have given an ample store to the public in their valuable works. Mr. C. H. Tatham has given likewise a tasteful and judicious series of examples of this kind, in his *Collection of Etchings of Ornamental Architecture, from the Antique at Rome.* Le Roy's, Le Pôtre's, and many other works of the like kind, may also be consulted with advantage.

GROTTO (from the French, *grotte*) is used for a little artificial edifice made in a garden, in imitation of a natural grotto.

The outsides of these grottos are usually adorned with rustic architecture, and their inside with shell-work, fossils, &c. finished likewise with *jets d'eau*, or fountains, &c.

A cement for artificial grottos may be made thus; take two parts of white rosin, melt it clear, and add to it four parts of bees' wax; when melted together, add two or three parts of the powder of the stone you design to cement, or so much as will give the cement the colour of the stone; to this add one part of flour of sulphur; incorporate all together over a gentle fire, and afterwards knead them with the hands in warm water. With this cement, the stones, shells, &c., after being well dried before the fire, may be cemented.

Artificial red coral branches, for the embellishment of grottos, may be made in the following manner: take clear rosin, dissolve it in a brass pan; to every ounce of which add two drams of the finest vermilion; when you have stirred them well together, and have chosen your twigs and branches, peeled and dried, take a pencil, and paint the branches all over whilst the composition is warm: afterwards shape them in imitation of natural coral. This done, hold the branches over a gentle coal fire, till all is smooth and even as if polished.

In the same manner white coral may be prepared with white lead, and black coral with lamp-black. A grotto may be built, with little expense, of glass, cinders, pebbles, pieces

of large flint, shells, moss, stones, counterfeit coral, pieces of chalk, &c., all bound or cemented together with the above-described cement.

The grotto at Versailles is an excellent piece of building. Solomon de Caux has an express treatise of grottos and fountains.

GROUND CILL. *See* GROUND SILL.

GROUND JOISTS, the joists which rest upon sleepers laid upon the ground, or on bricks, prop-stones, or dwarf walls; they are consequently only used in basements and ground-floors.

GROUND LINE, in perspective, the intersection of the picture with the ground plane. *See* GROUND PLANE.

GROUND NICHE, a niche whose bottom is on a level with the floor.

GROUND PLAN, the plan of the story of a house on the same level with the surface of the ground, or elevated only a few steps before the door. The ground floor is not always the lowest floor, the basement being frequently beneath it.

GROUND PLANE, in perspective, the situation of the original plane in the supposed level of our horizon. It differs from the horizontal plane thus: the horizontal plane is any plane parallel to the horizon; whereas the ground plane is a tangent plane to the surface of the earth on which we walk, and is supposed to contain the objects to be represented, the earth itself being considered as a spherical body.

The term *ground plane* is used in a more confined sense than that of *original plane*, which may be any plane, whether horizontal or inclined.

GROUND PLATE. *See* GROUND SILL.

GROUND PLOT, the plan of the walls of a building, where they first commence above the foundation; though it is more properly the piece of ground selected for building upon. For dwellings, its chief properties are a healthy situation, a convenient supply of water and other necessaries of life, and an agreeable aspect. If for trade or manufacture, it must be convenient for receiving the raw materials, and for exporting the articles manufactured.

GROUND RENT. Rent paid for the privilege of building on another man's land. In the neighbourhood of London it is very difficult to obtain freehold-land, and most of the building-ground, therefore, is let on long leases, subject of course to the payment of ground-rent.

GROUND SILL, or GROUND PLATE, the lowest horizontal timber on which the exterior walls of a building are erected. It chiefly occurs in timber buildings; or in buildings whose outside walls are formed of brick panels with timber framings.

GROUND TABLE. The top of the plinth.

GROUND WORK. *See* FOUNDATION.

GROUNDS, in joinery, certain pieces of wood concealed in a wall, to which the facings or finishings are attached, having their surfaces flush with the plaster. Narrow grounds are those to which the bases and surbases of rooms are fastened. Grounds are used over apertures, not only to secure the architraves, but also to strengthen the plaster. In order to keep the plaster firm, should the materials happen to shrink, a groove is sometimes run on the edge of the ground next to the plaster, or the edge of the ground is rebated on the side next to the wall; so that in the act of plastering, the stuff is forced into the groove or rebate, which prevents it from shifting when it becomes dry.

GROUP, in painting or sculpture, an assemblage of two or more figures of men, beasts, or other things which have some relation to each other.

GROUPED COLUMNS, or PILASTERS, those which consist of more than two. Nothing of this description is to be found among the ruins of the ancients; nor are they conformable to the strict rules of architecture, though some few examples exist in modern buildings.

GROUT, a thin semi-liquid mortar, composed of quick-lime with a portion of fine sand, which is prepared and poured into the internal joints of masonry. It is particularly used where the work consists of large masses of stone. The process is called *grouting*.

Grouting is also now generally used in street-paving.

GRY (Greek) a measure containing one-tenth of a line.

A line is one-tenth of a digit, a digit one-tenth of a foot, and a philosophical foot one-tenth of a pendulum, whose diodromes or vibrations, in the latitude of 45 degrees, are each equal to a second of time, or one-sixtieth of a minute.

GUARDS (from the French *garde*, a defence) in engineering, upright pieces of wood, nailed to the lock-gates of a canal. to prevent the barges from striking the planks of the gates.

GUERITE (French) in fortification, a sentry-box; being a small tower of wood or stone, placed usually on the point of a bastion, or on the angles of the shoulders, to hold a sentinel who is to take care of the ditch, and watch against a surprise.

GUILD-HALL, or GILD-HALL, the great court of judicature for the city of London, and other cities; where are kept the lord-mayor's court, the sheriff's court, the court of hustings, court of conscience, court of common-council, chamberlain's court, &c.

GUILLOCHI (Italian) an ornament in the form of two or more bands or strings twisting over each other, so as to repeat the same figure in a continued series by the spiral returnings of the bands. The term is also applied to the ornaments, consisting of bands turning at right angles, commonly called *frets*.

GULA, or GUEULE. *See* CYMATIUM.

GULBE, the same as GORGE, which *see*.

GULLIES, in engineering, a name applied in some places to the iron tram-plates or rails laid for the use of tram-waggons.

GULOICK, the same as IMPOST, which *see*.

GUNTER'S CHAIN, so called from the inventor, the chain commonly used by surveyors in measuring land. It is 66 feet long, or 22 yards, or 4 poles of $5\frac{1}{2}$ yards each; and is divided into 100 links of 7.92 inches each; 100,000 square links make one acre.

GURGOYLE, the same as GARGOYLE.

GUTTÆ (Latin) ornaments formed like the frustum of a cone, depending from the soffits of the mutules and regula under the band of the architraves of the Doric order. In several of the Grecian Dorics, the guttæ are cylindrical instead of being conical: their number on the soffits of the mutules is eighteen, disposed in three rows, each row parallel to the front.

They are sometimes also called *lachrymæ*, tears; and *campanæ*, or *campanulæ*, bells. Leon Baptista Alberti calls them *nails*. *See* DROPS, and DORIC ORDER.

GUTTER, in building, a channel for collecting and conveying the water from the roof, situated between the parapet and the inclined side of the covering, or between the inclined sides of a double roof, the intersection of the vertical plane of the wall and the inclined plane of the roof, or the two inclined planes forming horizontal lines. When two inclined sides of a roof meet each other at an internal angle, and form an inclined intersection to the horizon, the angle thus formed is called a *valley*. The external angles formed by two inclined planes are called *hips;* and hence hips are exactly the reverse of valleys, and thus we have the difference between gutters, hips, and valleys. The intersections of the planes

which form the sides of gutters are horizontal, but the intersections of the planes which form hips and valleys are inclined. Gutters for lead are formed partly by a boarding perpendicular to the plane of the walls, and partly by the inclined sides of the roof and the vertical planes of the walls, and are supported by horizontal bearers from the walls to the sides of the rafters, against which they are nailed at one end; the other end is supported close to the wall upon small posts or puncheons, which are notched and nailed to the bearers. The boarding, which is supported by the bearers, and which stands perpendicular to the planes of the walls, forms the bottom of the gutter, and is laid with a declivity in the parallel direction of the plane of the wall, of about an inch in 10 feet, and with steps, called *drips*, at every 12 or 18 feet. The drips are formed in planes perpendicular to the horizon and to the walls, rising about two, or two inches and a half, so as to add to the descent of the gutters, and at such distances from each other as are equal to the length of the sheets. Gutters are laid with lead of such weight, that the superficial foot contains from seven to twelve pounds, according to the stress that is supposed to be on the surface. The sheets are laid from 12 to 18 feet in length, as the descent for the water may permit. When there is a sufficient current for the water, shorter sheets of 12 feet in length are to be recommended in preference to longer ones, on account of the latter sometimes cracking by expansion, as all metals are liable to do. Cast lead is preferable to milled lead, as being more solid in its texture, and on this account is more to be depended upon when it expands, so as to keep from tearing asunder; but milled lead is equally thick throughout, and has its surface regularly smooth, properties which are not to be found in cast lead; therefore, wherever beauty and neatness of workmanship are required, milled lead must be employed. The goodness of cast lead depends upon the equality of its thickness, which cannot at all times be depended upon; and it should be observed, that plumbers themselves are divided in their opinion whether cast or milled lead ought to have the preference.

In London, parapet walls and leaden gutters are indispensable on account of the Building Act, as the numerous inhabitants are less liable to accidents from the falling of broken slates or tiles; and in cases of fire in the lower part of the building, they are convenient for making an escape from the danger, and also for assisting in extinguishing the flames. Several attempts have been made to substitute copper, but this material has not been found to have the desired effect, though zinc has been extensively used of late years instead of lead. The water is conveyed from the gutters by leaden pipes. In the country, dripping eaves are much used, and are to be preferred in elevated situations, as in the winter season the gutters and pipes are frequently stopped by snow or frost, so as to bring down the ceilings and plastering, injure the walls, and rot the timber; and thus not only render the building unfit for living in, but reduce it to ruin in the course of a few years. On this account, many of the first-rate houses suffer much by the overflowing of the water, unless the gutters are so constructed, that the water may escape before it finds its way into the building. Gutters should never be soldered where it can be avoided, particularly when the soldering would make the sheets of unusual length, as in this case it would be impossible to ensure it from cracking; the expenses of repairing would be frequent, and the ultimate effect ruinous. The thickest lead is used in gutters and flats, each generally of the same weight, while the hips and ridges are from five to six pounds to the foot, and most generally of milled lead.

The following are the regulations in the Metropolitan Building Act relating to parapets and gutters. "If an external wall adjoin a gutter, then such external wall must be carried up, and remain one foot at the least above the highest part of such gutter. And the thickness of an external wall so carried up above the level of the under side of the gutter-plate, and forming a parapet, must be at the least.

"In every such wall of the extra first-rate of the first class, and in every such wall of the first-rate of the second class, 13 inches thick; and

"In every other external wall, of whatever rate, or whichever class, 8½ inches thick."

GUTTERING. *See* GUTTER.

GUTTUS (Latin) a term among antiquaries for a sort of vase, used in the Roman sacrifices, to receive the wine and sprinkle it *guttalim*, drop by drop, upon the victim.

Vigenere on T. Livy, gives the figures of the guttus as represented on divers medals and other ancient monuments.

GYMNASIUM, a place fitted for performing exercises of the body.

The word is γυμνασιον, formed of γυμνος, *naked;* because they anciently put off their clothes, to practise with the more freedom.

Among the ancients, the gymnasium was a public edifice destined for exercise, and where people were taught, and regularly disciplined, under proper masters.

According to Solon, in Lucian's *Anacharsis*, and Cicero, *De Orat.* lib. ii. the Greeks were the first who had gymnasia; and among the Greeks, the Lacedæmonians; after them the Athenians, from whom the Romans borrowed them.

There were three principal gymnasia at Athens: the Academy, where Plato taught; the Lyceum, famed for Aristotle's lectures; and the Cynosargus, allotted to the populace.

Vitruvius describes the structure and form of the ancient gymnasia, lib. v. cap. 2. They were called *gymnasia*, because the champions performed *naked;* and *palæstræ*, from wrestling; which was one of the most usual exercises there: the Romans sometimes also called them *Thermæ*, because the baths and bagnios made a principal part of the building.

It appears, that so early as the time of Homer, they did not perform their exercises quite naked, but always in drawers; these they did not lay aside before the thirty-second Olympiad. One Orsippus is said to have been the first who introduced the practice: for having been worsted, by means of his drawers undoing and entangling him, he threw them quite aside, and the rest afterwards imitated him.

The gymnasia consisted of seven members, or apartments. M. Burette, after Vitruvius, recites no less than twelve. viz. 1. The exterior *portico*, where the philosophers, rhetoricians, mathematicians, physicians, and other virtuosi, read public lectures, and where they also disputed, and rehearsed their performances. 2. The *ephebeum*, where the youth assembled very early, to learn their exercises in private, without any spectators. 3. The *coryceum*, *apodyterion*, or *gymnasterion*, a kind of wardrobe, where they stripped, either to bathe or exercise. 4. The *elæothesium*, *alipterion*, or *unctuarium*, appointed for the unctions, which either preceded or followed the use of the bath, wrestling, pancratia, &c. 5. The *conisterium*, or *conistra*, in which they covered themselves with sand, or dust, to dry up the oil, or sweat. 6. The *palæstra*, properly so called, where they practised wrestling, the pugillate, pancratia, and divers other exercises. 7. The *sphæristerium*, or tennis-court, reserved for exercises wherein they used balls. 8. Large unpaved alleys, which

comprehended the space between the porticos and the walls wherewith the edifice was surrounded. 9. The *xysti*, which were porticos for the wrestlers in winter, or bad weather. 10. Other *xysti*, or open alleys, allotted for summer and fine weather, some of which were quite open, and others planted with trees. 11. The baths, consisting of several different apartments. 12. The *stadium*, a large space of a semicircular form, covered with sand, and surrounded with seats for the spectators. For the administration of the gymnasia, there were divers officers: the principal were, 1. The *gymnasiarch*, who was the director and superintendent of the whole. 2. The *xystarch*, who presided in the xystus or stadium. 3. The *gymnasta*, or master of the exercises, who understood their different effects, and could accommodate them to the different complexions of the athletæ. 4. The *pædotriba*, whose business was mechanically to teach the exercises, without understanding their theory or use. Under these four officers were a number of subalterns, whose names distinguished their different functions.

As to the kinds of exercises practised in the gymnasia, they may be reduced to two general classes, as they depend either on the action of the body alone, or as they require external agents or instruments. The former are chiefly of two kinds, *orchestice* and *palæstrice*.

The *orchestice* comprehended, 1. *Dancing*, 2. *Cubistice*, or the art of tumbling. 3. *Sphæristice*, or tennis, including all the exercises with pilæ, or balls.

The *palæstrice* comprised all exercises under the denomination of *palæstra;* as *wrestling*, *boxing*, *pancratia hoplomachia*, *running*, *leaping*, *throwing the discus*, the *exercise of the javelin*, and that of the *hoop*, denominated by the Greeks τροχος, which consisted in rolling an iron hoop five or six feet in diameter, beset with iron rings, the noise of which apprising the people to give way, afforded them also an amusement. Both strength and skill were requisite in directing this hoop, which was to be driven with an iron rod.

To these must also be added the exercises belonging to the medicinal gymnastics, as 1. *Walking*. 2. *Vociferation*, or shouting. 3. *Holding one's breath*.

The bodily exercises, which depended on external agents, may be reduced to *mounting* the horse; *riding* in a chaise, or other wheeled vehicle; *rocking* in beds or cradles, and sometimes *swinging:* to which may be added, the art of *swimming*. Hoffman enumerates no less than fifty-five sorts of gymnastic exercises.

The term *gymnasium* has descended to modern times. In Germany, the higher schools, intended especially as immediately preparatory to the universities, are termed gymnasia. Schools for the improvement of bodily strength, grace, or agility, are also called gymnasia. Within the last few years small portions of the newly-formed parks in the neighbourhood of London have been set aside for this purpose, and provided with the proper appurtenances for gymnastic exercises. To these the ancient word gymnasium is still applied.

GYNÆCEUM, (from the Greek γυνη, *a woman*, and οικος, *a house*,) among the ancients, the apartment of the women; or a separate place, in the inner part of the house, where the women kept themselves retired, employed in their spinning, out of the sight of the men.

Under the Roman emperors there was a particular establishment of gynæcea, being a kind of manufactories managed chiefly by women, for the making of clothes, furniture, &c., for the emperor's household. Mention is made of these gynæcea, in the Theodosian and Justinian code, and by divers other authors.

In imitation of these, divers of the modern manufactories, particularly those of silk, where a number of women and maids are associated and formed into a body, are called *gynæcea*.

GYPSOGRAPHY, a new method of engraving on plaster, to which this term has been given by the inventors. Gypsography, or metallic relief-engraving, is performed in the following manner. The surface of a copper-plate is prepared with a thin coating, or layer of plaster-of-paris, of uniform depth, through which the draughtsman etches with a point to the surface of the copper: he is enabled, as he proceeds, to observe the effect of every touch of the etching point. When the drawing or etching is completed, it forms a complete matrix or mould, and is cast in type-metal, in a similar manner to the process of stereotype-casting, and at once forms a block or plate, which must in every minute feature produce a perfect fac-simile of the original design of the artist, and from which, at the type-press or steam-machine, thousands of impressions can be worked in a few hours.

GYPSUM, a substance formed by the combination of sulphuric acid with calcareous earth.

Gypsum is found in a compact and crystallized state, as alabaster and selenite, or in the form of a soft chalky stone which in a very moderate heat gives out its water of crystallization, and becomes a very fine white powder, extensively used under the name of plaster-of-paris. This last is the most common, and is found in great masses near Paris, where it forms the hill Montmartre, near Aix in Provence, and near Burgos in Spain. It is found in smaller portions in various parts of Europe.

Of the different kinds of plaster the coarser sorts are employed, with the admixture of common lime-stone, for cements. The gypsum, which naturally contains carbonate of lime, makes very good cement; but that which has an admixture of clay and sand, affords a cement of an inferior quality.

The kilns in which the plaster-stones are burnt, are generally of a very simple construction; often they are built of gypsum itself. The fragments to be calcined are loosely put together, in such a manner as to form a parallelopiped heap, below which are vaulted pipes or flues, for the application of a moderate heat. The calcination must not be carried to excess, since in this case the plaster will be deprived of its quality of forming a solid mass when mixed with a certain portion of water. During the process of calcination, the water of crystallization rises as a white vapour, which, if the atmosphere be dry, is quickly dissolved in air.

On the river Wolga, in Russia, the burning of gypsum constitutes one of the chief occupations of the peasantry. They calcine all kinds of gypsum promiscuously, on grates made of wood, they then reduce the plaster to powder, pass it through a sieve, and form it into small round cakes, which they sell at from one, to one and a half rouble, per thousand.

In order to make use of the plaster, water is added to the powder, which is produced by pounding the calcined fragments; an operation performed either in mills constructed for the purpose, or by the hands of men. This work is exceedingly prejudicial to the persons employed in it, whose health is soon impaired by the pernicious effects which the dust of this substance has upon the lungs.

The less the gypsum intended for plaster is mixed with other substances, the better it is qualified for the purpose of making casts, stucco, &c.; the sparry gypsum, or selenite, which of course is the purest of all, is employed for taking impressions from coins and medals; and for those beautiful imitations of marble, granite, and porphyry, that are known by the name of *scaglioia*, derived from the Italian word, *scagli*,

or laminæ of selenite; the latter is vulgarly called *talc* in Italy and France, and also in England.

The *compact gypsum* of Kirwan (*alabastrite*, La Meth.; *albâtre gypseux*, de Lisle; *dichter gypstein*, Werner) when of a white, or yellowish, or greenish colour, semi-transparent, and capable of receiving a polish, is known among statuaries by the name of *alabaster*, which term is also retained as a secondary appellation in most books of mineralogy, and is certainly the *alabastrites* of Pliny, which is characterized by that author as a stone resembling gypsum. When its colours are disposed in bands or clouds, it is called, in the first case, *onyx alabaster*, and in the latter, *agate alabaster*. It not unfrequently contains a sufficient portion of carbonated lime to produce a brisk effervescence with nitrous acid; and hence has originated the confusion of authors, who make the circumstance of effervescence an essential distinctive character between the gypseous and calcareous alabasters. Its specific gravity seldom exceeds 1.9. Its fracture is compact, splintery, sometimes verging on the fine-grained foliated. In transparency, it is considerably superior to white wax, allowing light to pass readily through it, but not transmitting the forms of objects.

Gypseous alabaster is very easily worked, but it is not susceptible of a polish equal to marble. It is made into vases, columns, tables, and other ornamental articles of furniture; thin slabs of it have been used in one of the churches of Florence instead of window-glass. Its brittleness, however, and want of lustre, have caused it to be almost wholly superseded by more durable materials. Among the ancients, the most esteemed came from Caramania, Upper Egypt, and Syria: of the variety called *onyx*, the boxes for holding perfumes were mostly fabricated; thus, in Horace, we meet with "*Nardi parvus onyx*."

The *calcareous alabaster*, or sinter, (*albâtre calcaire*,) is a stone of the same family as stalactite, consisting chiefly of carbonate of lime, and exhibiting a considerable variety of colours; such as pure white, yellowish, greenish, reddish, and bluish gray: its fracture is striated or fibrous, the striæ sometimes parallel and sometimes divergent: its hardness is somewhat inferior to that of marble, which nevertheless does not prevent it from receiving a good polish: its specific gravity from 2.4 to 2.8: its transparency is nearly equal to that of white wax: it effervesces with acids, and burns to lime. Two sorts of alabaster are distinguished by statuaries, the *common* and *oriental;* under the latter of these are ranked the hardest, the finest, and the best coloured pieces; a number of sub-varieties are also produced by the colours being in veins, or dentritic, or in concentric undulating zones. Italy and Spain yield the most beautiful specimens: the inferior kinds are found in Germany and France. It is manufactured, like the gypseous alabaster, into tables, vases, statues, chimney-pieces, &c.

Many of the hot sulphureous waters rise out of the ground of a turbid wheyish colour, on account of a large quantity of gypsum and chalk, which they hold suspended, and in a state of half solution; as these grow cool, and lose their carbonic acid, the earthy particles are for the most part deposited, lining the bottom and sides of the channels in which they flow with a compact alabaster. Advantage has been occasionally taken of this circumstance to obtain very beautiful impressions of bas-reliefs, by exposing the moulds to a current of such water till they have become filled with the earthy deposit. The most remarkable of these springs in Europe, is that which supplies the baths of St. Philip in Tuscany: it is situated on a mountain near Radicofani, and forms the source of the little river Paglia. The water as it issues forth is very hot, springs out with great impetuosity, has a strong sulphureous odour, and holds in solution a large quantity of calcareous matter. From its very source it flows in deep channels, covered with a thick crust of stalactite, of a dazzling white, especially when the sun shines upon it; and which is harder or softer in proportion to the rapidity of the stream, and the obliquity of its fall. This circumstance suggested to Dr. Vegni, the idea of establishing on this mountain, a manufacture of artificial alabaster. For this purpose, he first collected a number of plaster-models, of the best bas-reliefs, in Rome and other places of Italy. These models serve to form the hollow moulds which are made of sulphur, according to the following process. The plaster model is rubbed over with boiled linseed oil, and surrounded with an edging of plaster, of the same height as the intended thickness of the subsequent bas-relief. Then sulphur, melted with just sufficient heat to make it flow, is poured on the plaster-model, and fills it to the height of the edging. The sulphur mould thus made, is placed in a kind of wooden tub, roughly put together, open at top and bottom, and of less diameter below than above. This tub has on the inside a false bottom, made of slips of wood laid cross-wise, in order to detain, for a short time, the water which dashes on them. Just above this is a row of wooden pegs, fastened to the tub, around its whole inner circumference, on which the sulphur mould is let down, and thus supported. The whole is then placed under the boiling spring, and inclosed with walls, to prevent it from being displaced by the wind. The water, which dashing on the moulds, deposits its earth both within and without them, giving the impression of bas-relief within, and disposing itself in an undulated surface on the outside. The hardness of the alabaster depends on the degree of obliquity at which the mould is placed in order to receive the dashing of the water. The more vertical its position, the harder is the alabaster. However, as the hardest models are not so white as the softer, the water is in some cases caused to make a circuitous course, in order to deposit all its grosser particles before it arrives at the mould. Even the softer ones, however, are as hard as Carrara marble, and surpass it in whiteness. The time required for these productions varies, according to the thickness, from one month to four. When the sulphur mould is sufficiently filled, and the ground of the model has acquired a thickness capable of supporting the figures, the whole is removed from the water; the wooden supports are broken by gentle strokes of the hammer, and the incrustation on the outside of the mould is chipped off by repeated strokes. Then the tub is struck with a smart blow of a hammer, which separates the model from the mould; generally, however, cracking the latter. The brilliancy of the models is completed by brushing them with a stiff hair-brush, and rubbing with the palm of the hand.

The composition of this alabaster is gypsum, mixed with a small proportion of carbonated lime. Dr. Vegni, after many attempts, succeeded in giving a fine black, or flesh colour, to the figures thus formed, by putting a vessel half full of colouring matter into the water, before it arrives at the mould. The colouring may be also varied, by protecting particular parts of the mould, while the water continues charged with colouring matter.

A spring of the same kind as that just described, and applied to similar purposes, is that of Guancavelica in Peru. The water rises from the ground into a large bason, boiling hot, and of a muddy yellowish-white colour. At a little distance from the bason, the water becoming cool, deposits calcareous matter in such vast abundance, as to fill large moulds with a compact stone, of which some of the houses of the town are constructed. The moulds of statuaries, in like manner, being exposed to the water, are filled with hard, con

fusedly crystallized alabaster, and the bas-reliefs thus produced, by polishing, become semi-transparent, and very beautiful. The images made use of by the Catholics of Lima, in their religious ceremonies, are said to be formed in this manner

Gypsum, pulverized by grinding or burning, has been used as a manure in France and America; and its fertilizing properties highly extolled. The use of it in this country, however, does not seem to have been attended with similar successful results.

H.

HACKING, in walling, the interruption of a course of stone, by introducing another course upon a different level, in consequence of the want of stones to complete the whole thickness; and thus frequently making two courses at one end of the wall or pier, of the same height with one course at the other end. The last stone laid in one height is frequently notched, to receive the first stone of the other, where the two heights commence. Hacking is never employed in good workmanship, and ought always to be guarded against by the superintendent, in case of work performed by contract where the contractor furnishes the stones. The term is used in Scotland, and particularly in Glasgow.

HALF-MOON, in fortification, the same as Raselin; which see.

Half Round, a semicircular moulding, which may be either a *bead* or *torus*.

Half Space, or Pace, as it is sometimes called, a resting place in a double parallel-flighted stair, where the higher riser of the lower flight is in the same vertical plane with the lowest riser of the higher flight. Also any raised platform such as the dais at the upper end of the halls of the middle ages.

Half-Teint, now more generally written Half-Tint, in painting, is, precisely speaking, the teint which lies exactly midway between the extreme light and the extreme dark which any colour is capable of receiving and reflecting. But painters use it in a far more general sense, viz., as inclusive of almost all the intermediate gradations between these two points; and therefore regard all objects, in what relates to colour and chiaro-oscuro, as composed of these three—*light*, *dark*, and *middle-tint*, or *half-tint*.

How much of the vision of objects is included within the sphere of half-tint, may be illustrated by imagining a ball of ivory placed opposite the sun, and viewed in nearly the same direction. In this situation, a small portion of it will reflect an image of the sun to the eye of the observer, which image, in the language of artists, will be termed its *high-light*. Towards its lower part a very small portion will be lost in shade. The far greater part of the ball, not reflecting light enough to come under the former of these denominations, nor being sufficiently deprived of it to receive the latter, is recognized under the term we are now discussing.

When pictures therefore represent the ordinary effect of day-light, where the illumination produces breadth of light, as the sun does, and still more in that kind of light produced by an illumined atmosphere when the sun is not clearly seen, it is evident that half-tint must be the reigning portion of tone and colour in them. Add to this that as objects recede in the plane of the picture from the source of light, they fall into comparative half-tint, their high-lights and shadows participating of the hue with which the intervening atmosphere envelopes them. From both these causes it may fairly be reckoned that nine-tenths at least, and a greater proportion occasionally, in subjects of this nature, will be half-tint, unless artificial shadows are introduced.

This being the case too much attention cannot be given to the management of the half-tint, as it produces the prevailing tone of colour in the picture. The difficulty lies in giving each colour introduced a gradation participating of the same hue, but at the same time preserving the true characters of the original colours in the whole. The reason of blending this one hue with all colours is made evident by considering the mode of operation adopted by nature, in which all gradations of shade are the effect of privation of light, and consequently of colour, which depends upon it, till at last every colour is lost in one dark hue, by the total lack of illumination; and that hue is alike with all. It is that hue, therefore, in different degrees, which produces the gradation from extreme light to dark, and which, acting equally on all, produces harmony in the effects by breaking each with a participation of itself.

This is the simplest mode of producing the half-tint, and maintaining it with an harmonious effect throughout the various parts of a picture. It will of course allow of intermixtures of reflections, either from parts of the same body, as in the folds of draperies, or from different coloured objects acting upon each other; and thus with its simplicity, richness and variety may be combined. What the hue of the dark shade with which it is produced, may be, depends entirely upon the taste of the painter, and the nature of the illumination. One only rule can be given. It ought, in its mixture with the light, or local colour, to produce a tint more cool than that in its hue.

Half-timbered Houses, such as were in use during the reign of Elizabeth, and the period immediately preceding. They consisted of wooden framing, filled in with plaster, and had a very picturesque appearance.

HALL, (Saxon) a word anciently used for a mansion-house or habitation.

Hall, (French, *salle*) in architecture, a large room at the entrance of a fine honse, palace, or the like.

Vitruvius mentions three sorts of halls: the *tetrastyle* which has four columns supporting the plafond or ceiling; the *Corinthian*, which has columns all round, let into the wall, and is vaulted over; and the *Egyptian*, which had a peristyle of insulated Corinthian columns, bearing a second order with a ceiling: these are called *œci*. The hall is properly the first and finest partition or member of an apartment; and in houses of ministers of state, public magistrates, &c., is that wherein they dispatch business, and give audience. In very magnificent buildings, where the hall is larger and loftier than ordinary, and placed in the middle of the house, it is called a *saloon*.

The length of the hall should be at least twice and a quarter its breadth; and in great buildings three times its breadth. As to the height, it may be two-thirds of the breadth; and if made with an arched ceiling, it will be rendered much handsomer, and less subject to accidents from fire. In this case, its height is found by dividing its breadth into six parts, five of which will be the height from the floor to the underside of the key of the arch.

A royal apartment is said to consist of a hall, or chamber, of guards, *aula prætoriana;* an ante-chamber, *procamera;* a chamber, *camera;* a cabinet, *conclave;* and a gallery, *porticus.*

Hall, also the principal apartment in the castles and mansions of the middle ages. These were usually of great length and size, having the chief entrance at one end, where was a screen surmounted with a minstrel's gallery. At the farther end was a raised platform or dais, with frequently an oriel window on one or both sides, where the principal guests dined. The fire-place was sometimes in the middle of the hall, with an aperture in the roof for the escape of the smoke; but at others at the side, with a chimney carried up in the walls. The aperture in the roof was often covered by an open lantern.

Amongst the larger halls in England, may be reckoned those of Westminster, and Crosby Hall, London; Eltham, and Penshurst, Kent; and that of Hampton-Court.

Hall, a public building erected for the administration of the police and justice of a city or corporation.

In this sense we say the *town-hall*, a *company's hall*, &c.

A stately building in the city of London, and the great court of judicature for that city, is called *Guild-hall;* and many of the City companies have very fine buildings, called their Halls, as the Goldsmiths' Hall, Fishmongers' Hall, &c.

Hall is also particularly used for a court of justice; or an edifice wherein there is one or more tribunals.

In Westminster-hall are held the great courts of this kingdom, viz., the Chancery, Exchequer, Queen's Bench, and Common-Pleas.

In adjoining apartments is likewise held the high court of parliament. Westminster-hall was the royal palace, or place of residence, of our ancient kings; who ordinarily held their parliaments and courts of judicature in their dwelling-houses, and frequently sat in person in the courts of judicature, as they still do in parliament.

The great hall, wherein the courts of Queen's Bench, &c. are kept, is said to have been built by William Rufus; others say by Richard I. or II. It is reckoned superior, in point of dimensions, to any hall in Europe; being 238 feet long, and 68 broad.

HALVING, a method of joining timbers by letting them into each other: it is preferable to mortising, even where the timbers do not pass each other, as they are less liable to be displaced by shrinking.

HAM, a Saxon word, signifying a house.

Ham, is also used to denote a street or village; whence it is, that the names of many of our towns end in *ham*, as Nottingham, Buckingham, &c.

HAMMER, an instrument used by carpenters, for driving nails, spikes, &c.; and by masons, for reducing stone, by breaking it in chips.

HAMMER-BEAM, a transverse beam at the foot of the rafter, in the usual place of a tie. Hammer-beams are constructed in pairs, having each a beam disposed on opposite sides of the roof. They are chiefly used in roofs constructed after the Gothic style; the end which hangs over, being frequently supported by a concave rib, springing from the wall as a tangent to the curve, and in its turn supporting another rib forming a Gothic arch with the counter-part. The ends of hammer-beams are decorated with various devices.

HANCES, or Haunches, the arcs of circles forming the ends of arches described with compasses, in imitation of elliptic arches. The figure representing the whole ellipsis is generally described with four circular segments, of which those that are opposite are equal to each other, and are bisected by each extremity of each axis; the two arcs which terminate the greater axis are called the *hances*, and those which terminate the shorter, the *schemes.*

HAND, a measure of four inches.

Hand-Irons. *See* End-Irons.

Hand-Rail, of a stair, a rail raised upon slender posts, called *balusters*, intended to assist persons in ascending and descending, and to protect them from falling down the well-hole.

Hand-Railing, the art of making hand rails by moulds, according to geometrical principles.

The art of forming hand-rails was never, before the publication of the *Carpenter's Guide*, subjected to any certain geometrical principle. The best method then known, was that of tracing it, like an angle-bracket, from the rise and tread of as many steps as the rail was supposed to occupy in winders, and making the face-mould of a parallel breadth, after obtaining the middle of the concave side. This is manifestly false; and the magnitude of the error will be greater as the circumference of the arc at the plan of the rail is greater than its chord. A rail, or any portion of a rail, formed upon this principle, could never stand vertically over its plan. The method here shown is founded upon the following principles: that if a cylinder be cut in any direction except parallel to the axis or base, the section will be an ellipsis; if cut parallel to the axis, its section is a rectangle; and if parallel to the base, its section is a circle.

Let us suppose a hollow cylinder made to a given plan, the interior will be concave, and the exterior convex; and let this cylinder be cut by any inclined or oblique plane, the section formed will be bounded by two concentric similar ellipses; consequently, the section will be at its greatest bread that each extremity of the greater axis, and at its least breadth at each extremity of the lesser axis. Therefore, in any quarter of the ellipsis, there will be a continued increase of breadth from the extremity of the lesser axis to that of the greater. Now a cylinder can be cut by a plane through any three points; therefore suppose we have the height of the rail at any three points in the cylinder, and cut the cylinder through these points, the section will be a figure equal and similar to the face-mould of the rail; and if the cylinder be cut by another plane, parallel to the section, at such a distance from it as to contain the thickness of the rail, this portion of the cylinder will represent a part of the rail with its vertical surfaces already wrought; and if the back and lower surface of this cylindric portion be squared to vertical lines, either on the convex or concave side, through two certain parallel lines, drawn by a thin piece of wood bent upon that side; the portion of the cylinder thus formed will represent the part of the rail intended to be made.

The principles upon which this art depends are those of cutting a right prism through any three given points in space, and of forming a development of any portion of the surface of the prism.

Thus, let the interior surface of the surrounding wall be that of an entire cylinder, the breadth of the steps divided into the frustums of equal and similar sectors, and the heights all equal, as is universally the case; then, if an interior cylinder surface be erected concentric with the wall, and the ends of the steps or surfaces to be trodden upon, and the planes of the risers tending to the axis be supposed to meet the interior cylindric surface, it is evident that if the portion of the intercepted surface contained between the indented line formed by the ends of the steps, and the circumferent line at the base be developed, or stretched out, all the points of the indented line formed by the outward or salient angles, will be in the same straight line, and all the points formed by the inward or re-entrant angles will be in another straight

line. It is equally evident, that this will not only be the case with cylinders, but with cylindroids, and every other description of prisms: that is, the points of the development of the indented line will always have such a position, that two straight lines parallel to each other may be drawn through the whole number of them.

The points of concourse of the salient angles, are called *the nosings of the steps.*

The line drawn through all the nosings of the steps, is called *the line of the nosings.*

Now let the portion of the cylinder before uncovered, be again enveloped, the development in this state becomes an envelope, and the line of nosings becomes a uniform helix, which would be the form of the rail for such a stair.

In this case, it would be easy to execute the rail to any length, in equal portions succeeding each other; for as the curvature of the helical line is everywhere the same, the same moulds which are used in the formation of one piece, would serve for every succeeding piece.

The steps around the circular part are termed *winders;* in these the risers tend to the axis of the cylinder.

Steps with their treads of the same breadth, are termed *flyers;* in these the risers are all parallel.

Very few staircases are entirely circular; but those of the semi-circular form, with winders in the semicircle, and flyers below and above, are very numerous; in such, the line of nosings would be crooked, and would form an angle at the junction of the flyers and the winders, and that round the semicircle would be an helix, consisting of half a revolution.

In the development of the steps, the line of nosings would consist of three straight lines; the two straight lines through the nosings of the flyers, would be parallel to each other, and each extremity of the middle one would join one extremity of each of the other two; but the angles are commonly taken away, by introducing a curve in their places.

A hand-rail, however, is not a mere helical line, but a solid, which may be contained between two concentric cylindric surfaces, or concentric prismatic surfaces. The principles are the same, whatever be the form of the plan. A solid erected upon any plan, is called *a prism;* a cylinder is therefore a round prism, and a cylindroid an elliptic prism. A hand-rail may stand upon a circular base, or partly circular and partly straight, or upon an entire elliptic base. In the construction of hand-rails, all prisms are excluded, which consist of plain surfaces; or, which is the same thing, where the sides of the plan consist entirely of straight lines; as in such cases, the rails themselves are either straight, or partly curved and partly straight upon the top and lower sides only, the sides being in vertical planes.

Let us therefore confine ourselves to prisms upon a circular or an elliptic base, or upon a base partly circular and partly straight; or lastly, upon a base partly elliptical and partly straight. The two last may be said to have compound bases or plans, and the two former simple bases or plans. Such a prism may be denominated *a curved prism.* The plan of any curved prism is understood to be of the same breadth, and consequently the solid erected thereon will be everywhere of the same thickness. The prism may therefore be a hollow cylinder, or a hollow clyindroid, or a concave body, partly cylindric and partly straight; the latter may be open on one side, and may have the four planes which join the curved surfaces parallel to each other, and tangent to each of the cylindric surfaces.

Let us therefore suppose such a prism as that last mentioned, to be cut entirely through its vertical surfaces, in such a manner that any point in the surface of division may coincide with a straight line everywhere perpendicular to the external prismatic surface, then, every such line will be parallel to the plane of its base, and those lines in the cylindrical part of the prism will tend to the axis. Now it is evident, that the cut, or dividing surface, will not be a plane, but will wind or twist between the cylindric surfaces. It is also evident, that the cut may pass through a line drawn in any manner we please, in one of the prismatic surfaces; or, that the development of this line may have any degree of curvature in the whole length, or in any portion of the length, or may even be a straight line. One of these being supposed to be the case, let the upper part of the prism be taken away, then the upper surface of its remaining part will be brought to view; let a line be drawn on the exterior surface parallel to the arris, and another on the concave side parallel to its arris; and let another cut or dividing surface be made to pass through the two lines thus drawn, and let the upper part be removed by this division; then the part thus removed will form a solid helix, or kind of half screw, which may be either uniform in its upper and lower surfaces, or have any degree of curvature in any part that may be required, according to the development before mentioned. This is the form of the rail for such a stair; but to form the solid helix, without cutting it from a hollow curved prism, is what is required in hand-railing.

Now, as two of its sides are actually cylindrical, and would be vertical if placed in position, and the other two winding surfaces may be formed to any development desired; take any determinate portion of the helical solid, as a quarter of a revolution, or perhaps something more, as occasion may require, and endeavour to form such a portion, or wreath, out of a thin plank, instead of cutting it from a solid curved prism. Before this can be done, it is necessary to understand the principle of cutting a prism through any three fixed points in space, by a plane passing through those points; the points may be in the surface of the prism itself, and may be either all in the concave side, or all in the convex side; or partly in the concave side, and partly in the convex side;—that such a supposition is possible will readily appear, since any three points are always in the same plane; and, therefore, the plane may cut the prism through any three given points.

The three points through which the section is cut, are said to be given, when the seats are given on the plane of the base of the prism, which plane is understood to be at right angles to the axis of the prism, and when the distances or heights from the seats to the points themselves are given.

It is always to be understood, that the three seats are not in a straight line, and consequently the three points themselves not a straight line.

The seat of a point in space on any plane, is that point in the plane where a perpendicular drawn through the point in space cuts the plane.

In the helical solid, the winding surface connecting the two prismatic surfaces, has been defined to be of such a property as to coincide with a straight line perpendicular to the exterior prismatic surface, and, consequently, if the axis of the curved prism be perpendicular to the horizon, every such line will be parallel to the base; now, let the seats of three such lines be given on the plan, viz., let each extreme boundary be one, and let another be taken in the convex side passing through the point, which would give the middle of the development of the said side of the plan; the three seats would be terminated by the convex and concave sides of the plan, and will always be perpendicular to the convex side, and equal in length to each other. Call the three level lines,

of which their seats are given, *the lines of support;* let a plane be laid on the three lines of support, and it will rest either upon three points, or upon one of the said lines and two points; hence the points which come in contact with the plane, will be at one extremity of each line of support; let each of the points, which come in contact with the plane thus posited, be called *a resting point.* The three resting points are the three points in space, through which the plane is supposed to pass that cuts the curved prism.

Now because each line of support has two extremities, there will be six extreme points in all, but as only three can be resting points, unless the plane coincides with one of the lines of support, it will be proper to show, which three of the six are the resting points. Let the plane, thus laid upon some three extremities of the lines of support, be continued to intersect the base of the curved prism, then the nearest extremity of the seat of any line of support, to the intersecting line, is the seat of the resting point of that line. For this purpose, let a development of the convex side of the rail be made according to the plan and rise of the steps. The part of this development that is made to bend round the concave or convex cylindric surface of the helical portion or wreath, is called a *falling-mould,* which is supposed to be brought to an equal breadth throughout its length. Only one falling-mould is used in the construction of hand rails. Let therefore the falling-mould for the convex side be constructed, and let two straight lines be drawn from the ends of the upper edge of that part of the falling-mould corresponding to the ends of the wreath perpendicular to the base of the whole development; also let another intermediate line be drawn parallel to the other two. so as to bisect the part of the base intercepted by the said two parallels, the three parallels will give us the heights of the three resting points, the shortest height is at one extreme, and the longest at the other. Suppose now the shortest of these three heights taken from each of the three, and the remainders taken as heights, instead of the whole, then the height of the first resting point will be nothing and will therefore coincide with its seat; and if the middle height be less than half the length of the remaining height, the seats of the resting points will be the first and second extremities of the first and second lines of support taken on the convex side, and the extremity of the third on the concave side. The first resting point is a point in the intersection of the plane of the base with the inclined plane.

The process is now completely reduced to that of finding the section of a prism through three given points, which suppose to be done, and the plane of section will touch the supposed wreath at the resting points of each line of support without cutting the wreath at any such line; then the three lines of support will be on the same side of the plane, viz., on the under side. Suppose now another section taken below, and parallel to the former, so that the wreath may be just contained between these parallel sections or planes, and the distance between the two sections will represent the thickness of the plank. The section of the prism through its vertical surfaces is called *the rake* or *the rake of the plan;* and a mould being cut to the rake is called *the face-mould.*

The manner of forming a helical line or screw is as follows:—

Plate VIII. *Figure* 1. Divide the circumference of the outer circle of the base into equal parts; draw a line through the centre to represent the axis of the cylinder, parallel to the axis, and through the points of division in the outer circumference draw lines; divide the line of heights or the line representing the axis, into as many equal parts as the circumference of the base is divided into, and through the points of division draw lines at right angles to the axis, intersecting, as in the figure; through the points of intersection, draw a curve which will represent the helix, or one of the arris lines of the rail.

Figure 2.—The projection of the solid helix coiling round the cylinder; which helix represents the hand-rail before it is moulded.

Figure 3.—No. 1.—A solid section of a cylinder contained between two parallel planes, a part of the side of this solid contained between two planes passing through the axis is the form of a piece from which the rail is made after it is cut out of the plank. No. 2, half the solid section, No. 3, the inclination of the cutting planes.

Such large portions as these, however, are by no means proper to be employed in hand-railing, as the size would necessarily occasion the fibres of the wood to run in a transverse direction to the length of the rail, and consequently weaken it, but they are useful in this place to convey clear ideas of the principle upon which the art is founded.

Figure 5.—No. 1.—The proper form of a part from which a portion of the rail is to be made after it has been cut out of the blank; exhibiting the convex side of the same, and the upper plain surface, which is that of the plank. No. 2. The concave side of the same, with the joints and lower surface of the plank.

Figure 4.—A portion of the rail completely squared with the concave side, the joints, the bottom part of the upper winding surface, and the upper part of the lower winding surface, brought into view. No. 3. The convex side of the same, showing the upper part of the upper surface, and the lower part of the lower surface.

The business of hand-railing is to find the mould for cutting a rail out of planks.

Though hand railing is only treated of here, as connected with cylindrical well-holes: it is equally applicable to rails erected upon any seat whatever.

The mould, which applies to the two faces of the plank, regulated by a line drawn on its edge, so as to be vertical when the plank is elevated to its natural position, is called the *face-mould;* or sometimes the *raking-mould.*

A parallel mould, applied and bent to the side of the rail-piece, for the purpose of drawing the back and lower surface (which are to be so formed that every level straight line, directed to the axis of the well-hole, from every point of the side of the rail formed by the edges of the falling-mould, shall coincide with the surface) is called a *falling-mould.*

When the upper surface of the plank is not at right angles to a vertical plane passing through the chord of the plan, in order to cut the corresponding portion of the rail out of the least thickness of wood, the plank is said to be *sprung.*

A right-angled triangular board, made to the rise and tread of a step, is called the *pitch-board.*

In a stair-case, where there are both winders and flyers, two pitch-boards will be concerned, of different treads, but of the same heights, as the height of the steps must be equal.

The bevel by which the edge of the plank is reduced from the right angle, when the plank is sprung, in order to apply the face-mould, is called *the spring of the plank;* and the edge or narrow side thus reduced, is called the *sprung edge.*

The bevel by which the face-mould is regulated to each side of the plank, is called the *pitch.*

The formation of the upper and lower surface of a rail is called the *falling of the rail.*

The upper surface of the rail is called *the back.*

The first thing in the practice is to spring the plank, then to cut away the superfluous wood, as directed by the draughts formed by the face-mould. This may be cut so very exactly

with a saw, by an experienced hand, as to require no further reduction; and when set in its place, the surface on both sides will be vertical in all parts, and in a surface perpendicular to the plan. In order to form the back and lower surface, the falling-mould is applied to one side, which is generally the convex side, in such a manner, that the upper edge of the falling-mould at one end may coincide with the face of the plank, the same in the middle, and to leave so much wood at the other end to be taken away, as not to reduce the plank on the concave side. The piece of wood to be thus formed into the wreath or twist, being agreeable to three given heights. This description is general, in order to comprehend the following construction of the moulds themselves, which when explained, we shall then enter into a more particular detail of their application.

To construct the falling and face-moulds of a rail to a level landing, supposing the plane of the plank to rest upon the middle point of the section, which separates the upper and lower circular parts, and to rest upon the line parallel to, and in the middle of the straight part, so as to have the grain of the wood parallel.

Plate I. *Figure* 1.—The falling-mould of the hand-rail: B C the extension of the semicircular part; B A and C D the treads of the adjoining flyers.

To find the extension of the semicircular part, from the middle point, I, of B C, draw I K L perpendicular to B C; divide the radius I K into four equal parts, and repeat one of these parts from K to L seven times; draw the diameter M N parallel to B C; join L M and L N, and produce each of these lines to B and C; then B C is the rectification of the semi-circumference M I N. Draw B T and D H perpendicular to A D; make B E equal to the height of a step; I O on the straight line I L, one step and a half; C F equal to the height of two steps; and D H equal to the height of three steps; join A E and H F, and through O draw P Q parallel to B C; produce A E and H F to meet P Q at P and Q; then cut off the angles at P and Q by equal touching curves, one at each; then A E O F is the middle of the falling-mould; and as the rail is generally made two inches deep, draw two parallel lines each an inch distant from this central line, and S U & will be the upper edge of the falling-mould, and δ Y J the lower edge.

To find the face-mould of the hand-rail.

Figure 2.—At any convenient place lay down the half plan, *a b c d e f a*, of the hand-rail; *a b c f* being the straight part of the rail, and *c d e f* the plan of the circular part; draw *g e d* parallel to *a f* or *b c;* bisect *d e* at *h*, and draw *h i* perpendicular to *g d;* make *h i* equal to I U, *Figure* 1, and the angle *h i k* equal to the angle G H F; let *h* represent the middle point of the section between the two circular parts; and suppose *n* to represent the resting point in the middle of the section, which separates the straight and circular parts; make B R, *Figure* 1, equal to *c b* or *f a*, *Figure* 2, and draw R S, *Figure* 1, perpendicular to A B, cutting the upper edge of the falling-mould at S; make *h r*, *Figure* 2, equal to B T, *Figure* 1, and draw *r s*, *Figure* 2, parallel to *g d*, cutting *i k* at *s;* make *h m* equal to *r s*, and join *m n*, which is the directing ordinate; from *k* draw *k l* parallel to *m n*, and *k l* is the intersection of the plane of the plank; find the countersection *k t*, as in the SECTIONS OF CYLINDERS, or as in the subsequent part of this Work, under SOLID ANGLES.

To find any point in the curve of the face-mould.—Draw *u v w* parallel to *k l*, cutting *k d* at *u*, and the concave side of the plan at *v*, and the convex side at *w*; draw *u x* parallel to *h i*, cutting *k i* at *x;* draw *x y z* parallel to *k t;* make *x y* equal to *u v*, and *x z* equal to *u w;* then *y* is a point in the concave side of the face-mould, and *z* is a point in the convex side. The pitch-bevel shown by the dark lines, is found by drawing a vertical line to the pitch-line, and the angle formed by these lines is the pitch-bevel.

In this manner as many points may be found as will be necessary to complete the concave and convex sides of the falling-mould; or rule each system of lines at the same line, thus; take as many points in the convex side of the plan as will be found requisite; through all these points draw lines parallel to *k l*, to cut *g d;* from all the points of division in *g d* draw lines parallel to *h i*, cutting *k i;* through all the points of division in *k i* draw lines parallel to *k t;* terminate each line from the point of intersection equal to the corresponding outer and inner ordinates of the plan, and through the points found by its concave side draw a line; also through the points found by the convex side of the plan draw another curve: then the corresponding points found for each extremity of the plan will complete the face-mould. It is evident that the parts 3-4, 5-6 of the face-mould corresponding to *a b*, *c f* on the plan, is a parallelogram, therefore if the point 6, where the concave side and the straight parts meet, and the point 5, where the convex and straight parts meet, are found and joined by the line 5-6; and if 5-4 and 6-3 be drawn parallel to *k i*, and the point *q* corresponding to *o*, be found, by drawing 4-3 through *q*, the straight part of the face-mould will be completed.

The line of separation 5-6 will be more exactly determined as follows: Through *n* draw *n* 7 parallel to *h i*, cutting *k i* at 7; then find only one of the points 5 or 6, say 5; draw 5-7; then 5-6, which is a part of 5-7, is the line of separation.

This face-mould will answer for the upper, as well as the lower half.

The angle *l* 2-1 is the spring of the plank, and is found in the same manner as in solid angles, and having the intersection and cointersection, the face-mould is found as in the sections of a cylinder. The face-mould might have been found as in *Figure* 3, by taking the heights from a line drawn over the face-mould parallel to A D, *Figure* 1, and laying the plan upwards, as in *Figure* 3, then proceeding with the operation downwards, as directed in *Figure* 2 upwards. Or, if the drawing is inverted, the line V H, *Figure* 1, will become the base of the heights, and everything else will be in the same position as in *Figure* 2.

In the application of the moulds, imagine the plank set up to the pitch, and in the same way spring the edge from the under side for the lower piece, and from the upper side for the upper piece. To apply the moulds to the plank, now supposed to be sprung or beveled, take the pitch and draw the vertical line, the stock of the bevel being applied to the acute edge of the plank, upwards or downwards, as the case may require: then draw a line equal to the distance of 3-6 from *k i*, upon each plane of the plank parallel to the side; then the point 8 being kept to the end of the vertical line, and the side 3-6 upon the parallel line, draw round all the edges of the mould; turn the mould to the other side, apply the point 8 to the other end of the vertical line, and the part 3-6 upon the line drawn parallel to the face, and draw round all the edges as before; then cut away the superfluous stuff. The sides of the piece intended to form the twist must be perfectly cylindrical, and all the parts so formed, that a straight line or edge may apply to any point, at the same time that it coincides with the surface, and is parallel to the vertical line drawn on the edge of the plank.

The falling-mould is thus applied: Draw a line upon the ends of the solid piece, at right angles to the vertical sides, from *zero* at each end, next to the upper side; then apply the upper edge of the face-mould next to the top of the plank, and each end to the corresponding end of the piece, bending it so that all parts may be in contact with the stuff; then

draw a line round all the edges, and it will show the superfluous wood to be cut off.

To construct the face-mould of a hand-rail to a stair upon a level landing, in two parts, round a semicircular newel; so that when the two pieces are united or fixed in their places, the grain or fibres of the wood will mitre at the joint.

Plate II.—Let *Figure* 1 be the rail stretched out, as in the preceding example: draw the chord of the rail, *i k*, *Figure* 2, No. 1; bisect the end *k u* at *a*, and the other end *i w* at *c;* draw *j z b* c perpendicular to the chord *k i*, cutting the concave and convex sides at *z* and c; make *z b* equal to *i c*, and E C, *Figure* 1, equal to *w* C, *Figure* 2, No. 1, extended: draw C D, *Figure* 1, perpendicular to A E, cutting the upper edge of the falling-mould at D, and the lower edge at H. In *Figure* 2, No. 1, draw *a d* perpendicular to *k i*, and *c e* parallel to *a d;* make *a d* equal to A B, *Figure* 1; *c e*, *Figure* 2, No. 1, equal to E F, *Figure* 1; and *c f*, *Figure* 2, No. 1, equal to C D, *Figure* 1; join *a c* and *d e*, *Figure* 2, No. 1; draw *f g* parallel to *a c*, cutting *d e* in *g;* draw *g t* parallel to *e c*, cutting *a c* in *t;* join *t b;* draw *c y* parallel to *t b*, cutting the convex side of the plan at *y;* produce *y c* to cut the chord *k i* at 2; draw 2 *h* parallel to *c e;* make 2 *h* equal to *c e;* draw *k* K parallel to *a d;* make *k* K equal to *a d;* join *h* K; produce *h* K and *i k* to meet each other in *l;* draw *l m* parallel to *t b:* from any point, *m*, in *l m*, draw *m* 3 perpendicular to *l i;* produce *i l* to *p*, cutting *m* 3 at 3; through 3 draw 4 *n* perpendicular to *h l;* produce *h l* to 4; make 3 *o* on *p l* equal to 3-4; join *o m;* make 4 *n* equal to *o m*, and join *n l:* then draw ordinates on the plan parallel to *l m*, to cut both sides of it, and also the chord *k i;* from the intersections in *k i*, draw lines parallel to *c e*, to cut *h l;* from the points of section in *h l*, draw lines parallel to *l n;* make the lines thus drawn parallel to *l n*, equal to the corresponding lines on the plan; and a curve drawn through these respective points will give the face-mould.

In drawing ordinates upon the plan, care should be taken that an ordinate be drawn through the points upon each side of the plan at the line of separation of the straight and circular parts, and also through each extremity of the ends; or, by finding M N, the line of separation, and the point K, the point L will be found by drawing K L parallel to N M, and M L parallel to N K; and thus the portion M N K L, corresponding to *v x k u* on the plan, will be obtained.

The angle *p o m* gives the spring-bevel, *Figure* 2, No. 3; and the angle *s r q* gives the pitch-bevel, *Figure* 2, No. 2. The face-mould is applied to the plank by laying the points P and K close to the edge that is sprung; then drawing the pitch-bevel, No. 2, from either point P or K; for it is not necessary to draw them from both, as the corresponding point will be found upon the other side of the plank; then proceed with the remaining parts as before directed.

To spring the plank for a level landing through two given points, so as to parallel the grain.

Plate III.—Let No. 3 be the falling-mould, as before: draw any line, C A, for the base of the heights of the face-mould; then C D is the lower height, where the two wreathed pieces meet, and A B is the upper height, making allowance for the squaring of the joint. Lay down the plan A *k* C, No. 1; draw C *n* parallel to A *k;* draw A B perpendicular to A *k;* make A B equal to A B, No. 3, and the angle A B E, No. 1, equal to the angle V W S, No. 3; produce A *k* to E; draw C D parallel to A B; make C D equal to C D, No. 3, and the angle C D F equal to the angle A B E, that is, equal to the angle V W S, No. 3: produce *n* C to F; join F E; in F E take any point, E, and draw E I perpendicular to F C, meeting it in I; from I draw I K perpendicular to F G, cutting it in L; make I H equal to I L, and join H E; make L K equal to H E, and join F K; then F E is the director of the ordinates of the base, and F H that of the face-mould. Proceed with the rest as in *Plate* I. *Figure* 1.

No. 2 shows the other mould; but it must be observed, that one mould is sufficient for both wreaths.

Plate IV. shows the falling and face-moulds of a rail with winders. As to the method of laying down the moulds from three given heights, the principle is the same as described in *Plate* I. for a level landing. It therefore only remains to speak of the manner of forming the butt-joints. Draw a line at right angles to the sides of the falling-mould, through the middle of the vertical line, where otherwise would have been the splice joint; from the end of this line draw another at the upper edge, and also one from the under edge, perpendicular to the base line; then the middle height being taken as usual, the remote line is the height of the face-mould.

Thus, H I, No. 1, is the height of *h i*, No. 2; K L, No. 1, the height of *k l*, No. 2; and M N, No. 1, the height of *m n*, No. 2; the remaining part of the construction is as usual. No. 3 is the upper face-mould, taken from inverted heights: or the falling-mould may be considered as inverted. The same letters are put upon both constructions, to show the similar parts. Here are eight winders, all drawn to a scale, to show the proportion of the parts in practice. This hand-rail requires two moulds, on account of the middle of the falling-mould being much higher than the hypothenuse of the winders.

Plate V. shows the falling and face-moulds for a rail constructed as in *Plate* IV. The only difference is, that in this Plate the middle of the falling-mould is the hypothenuse of the wreath. This situation of the falling-moulds will cause both the face-moulds to be identical: that is, their figures will be equal and similar, so that considerable time will be saved in the preparation. This position, and the identification of the moulds, may always be adopted when the distance between the opposite parts of the string is more than ten inches. The mode of making the height of the rail in the middle of the winders the same as that of the flyers, is practised by several celebrated staircase hands, though it is nothing more than a mere matter of opinion, and may be adopted or not, at the option of the architect, or of the workman, if left to him.

It is worthy of notice, that the springing of the plank is of the utmost consequence in the saving of stuff, where the well-hole is wide; but where it is narrow, very little will be gained by it.

To draw the scroll of a hand-rail, and to find the mould for executing the twist.

Plate VI. Figure 1, No. 1, represents the plan of the rail. The scroll is drawn by centres, in the following manner: Make a circle in the centre, $3\frac{1}{2}$ inches in diameter; divide the diameter into three equal parts; one of which subdivide into six equal parts; set one part from the centre upwards, draw a line from the end of that part, at right angles, towards the left hand, and limit this perpendicular to two parts; from the end of the last perpendicular draw a third downward, limiting it to three equal parts; proceed in this manner till six perpendiculars have been drawn, each differing in length by one from the preceding, and the form of a spiral fret will be obtained. The points of concourse of every two lines will give the centres, which are six in number, besides the centre of the circle, and are numbered in order from such centre: draw a straight line downward from the first centre, by continuing the line already drawn till it cuts the circle: continue the second perpendicular to the right hand, and the third upwards to the left hand; these will form the limiting lines for the four arcs, which will complete one revolution.

Continue the lines in the same order for the next revolution, or for the portion of it required. Begin with the centre next to that of the circle for the first centre, and describe a quarter arc from the point of contact of the circle to the next limiting line; then around the second centre, with the distance to the intersection of the preceding arc, on the preceding limiting line, describe another arc; proceed in this manner till the whole spiral is completed. Set the breadth of the rail from *o* to *a*, and describe another spiral by the same centres, by turning the arcs the contrary way, till the last arc of the spiral cuts the first; which will complete the scroll of the rail; then the addition of a part of the straight of the rail will complete the whole.

The outer spiral consists of one revolution and a half, and the inner of only about half a revolution, which also makes the scroll itself appear only half a revolution; but if more is required, every additional centre will add a quarter of a revolution to the scroll.

To find the face-mould for the shank of the scroll.

Figure 1, No. 1. Lay the base of the pitch-board upon the outside of the shank of the scroll, with the acute angle turned to the outside, or largest convexity: draw a line parallel to the base of the pitch-board, to touch the convex side of the scroll next to the straight part; let this line cut the outside of the rail at 6: between 0 and 6 take any number of intermediate points, 1, 2, 3, 4, 5, and draw lines perpendicular to the base of the pitch-board, to cut the hypothenuse of the said pitch-board; from the points of section draw lines at right angles to the hypothenuse; let the perpendiculars parallel to the base line of the pitch-board be continued downwards, to cut the concave side of the shank; and let one of the perpendiculars be drawn from the concave, and another from the convex side of the rail, where it is intersected by the line parallel to the base line; make all the lines at right angles to the hypothenuse equal to the respective ordinates of the shank taken from both concave and convex sides of it: then curves being traced, and the straight parts joined to the angular points, will be the face-mould.

To find the falling-mould.

Divide the distance between 0 and 6, *Figure* 1, No. 1, into six equal parts, and run the chord on the convex side as far as the rail is required to fall: upon any convenient line, A D, No. 2, run the chord of the part from 0 to 13; place the angular point, C, of the pitch-board at 4; with the base A C, upon A D, tange the angle B C D made by the hypothenuse of the pitch-board and the line A D, with a curve to touch at B and D, as shown at No. 3; then draw another curvilinear parallel, containing the depth of the rail between the two curves; and the falling-mould, No. 2, will be completed as far as the rail has a descent, which ends at 13. The block of the scroll, which is the remaining part after the shank is taken away, is wrought out of a solid piece of wood, the height of the perpendicular upon 0. The shank is squared in the same manner as shown in *Plate* II.

No. 4. The falling-mould for the concave side of the rail is exhibited here, in order to show, that if the ramp and the curve of the scroll do not begin together, and if the rail be made absolutely square, that is, having all its plumb sections rectangles, and the convex side made agreeable to its falling-mould, with an easy curve, it will be impossible to form the back with a regular curve on the concave side, and a hump will always be formed. Therefore, in reducing the hump to an agreeable curve, the rail will be thrown out of the square; but the degree by which it deflects from the truth is so small as not to be perceived.

The inside of the falling-mould is formed by taking the stretch out of *a b*, *b c*, *c d*, &c., of the corresponding parts 0 1, 1 2, 2 3, &c., in No. 1, and applying them from *a* to *b*, from *b* to *c*, from *c* to *d*, &c., No. 4; then drawing the perpendiculars from the points *a*, *b*, *c*, &c., and transferring thereto the corresponding perpendiculars insisting upon 0, 1, 2, &c., No. 2, and then tracing the curves. According to the principles of hand-railing, a vertical or plumb section of the rail at right angles to the cylindric sides, or tending to the axis of the cylinder, is level on the back; therefore, as the concave and convex sides of the plan of the scroll are concentric circles, the arc on the concave side, so far as relates to the same quadrant, will be divided equally, as well as the outside; and therefore drawing lines to the centres from the points of section on the convex side will divide each quadrant equally, and the lines thus radiating will be perpendicular to the curve on both sides of the plan; all the parts throughout the same quadrant will be equal on the concave side as well as on the convex side; and on the convex side the parts will be equal throughout all the quadrants; but on the concave side the parts of each succeeding quadrant, in turning towards the centre, will be quicker than those in the preceding quadrant. In the part of the rail which is straight upon the plan, the sections at right angles to the sides divide each side into equal parts, and the parts on the one side equal to those of the other: hence the reason why the hump takes place at the junction of the ramp and twist.

If a scroll is made agreeable to the form of the plan as struck round centres with compasses, it will always appear to the eye as if crippled at the separating section of the straight and twisted parts. To remedy this defect, the curve of the vertical sides, or that which relates to the plan, ought to be extended with an easy curve into the straight part.

No. 5. An elevation of the shank of the scroll. The portion of the plan is taken from No. 1, and the heights which give the curves are taken from the falling-mould, No. 2; its use is to show the thickness of stuff which is contained between two parallel lines; the lower line comes in contact with the projection at two points, the upper one comes in contact with the projection in one point only.

To show the method of forming the curtail of the first step.

Plate VII. *Figure* 1, No. 1.—Draw the scroll as in the preceding Plate; set the balusters in the middle of the breadth, putting one at the beginning of every quarter; then the front of the balusters is in the plane of the face of the riser, and the opposite side in the plane of the string-board: set the projection of the nosing before the baluster on both sides, and draw two spiral lines parallel to the sides of the scroll, till the curves intersect each other, and they will then form the curtail end of the step, as required, F G H I K represent the convex side of the scroll; L M N, the convex side of the curtail; and A, B, C, D, E, the centre points of the balusters.

No. 2 shows the profile of the curtail, the end of the second step, and part of the end of the third.

Figure 1, No. 3, shows the centres for drawing the curtail, which are the same as for drawing the scroll.

To describe a section of the rail, supposing it to be two inches deep, and two and a quarter inches broad, the usual dimensions.

Figure 2.—Let A B C D be a section of the rail, as squared. On A B describe an equilateral triangle, A B *g*; from *g*, as a centre, describe an arc to touch A B, and to meet *g* A and *g* B: take the distance between the point of section in *g* A and the point A, and transfer it from the point of section to *k*, upon the same line *g* A; join D *k*; from *k*, with the distance between *k* and the end of the arc, describe another arc, to

meet D k; with the same distance describe a third arc, of contrary curvature, and draw a vertical line to touch it; thus will one side of the section of the rail be formed. The counter-part is formed by a similar operation.

Figure 3 is the most simple form for the section of a rail, being that of a circle.

To describe the mitre-cap of a rail.

Figure 4.—Describe a circle, $a\ e\ b\ d$, to the intended size (the proportion here between the rail and the cap is as 2 to 3); draw the diameters $a\ b$ and $e\ d$ at right angles; produce $e\ d$, and place the middle of the section of the rail upon $e\ d$; draw B Q to touch the section of the rail, and to cut the circle $a\ e\ b\ d$ in Q; draw the side P Q of the mitre; draw A B to meet the points of contact, A and B, of the lines parallel to $e\ d$, which are tangents to the section. Then to find any point in the curve of the section of the mitre-cap: let G be a point in the section of the rail; draw G k, meeting P Q in k; from the centre of the circle $a\ e\ b\ d$, describe an arc, $k\ f$, meeting $a\ b$ in f; from the point of section, f, draw $f\ g$, perpendicular to $a\ b$; and make $f\ g$ equal to F G.

All other points are found in the same manner; or a series of lines may be drawn from any number of assumed points in the section, and lines parallel to $e\ d$, drawn from them to cut P Q; arcs may then be described from each point of section to meet $a\ b$, and perpendiculars drawn from the points of section in $a\ b$; all these perpendiculars should be made equal to the respective ordinates of the section, and a curve drawn through their extremities will form the curve of the mitre-cap.

HANGING, of doors, or shutters, the act of placing them upon centres or hinges, for the convenience of opening and shutting. *See* HINGING.

HANGING STYLE, the style of a door or shutter, to which the hinge is fastened.

The term is also applied to a narrow style fixed on the jamb, on which the door or shutter is sometimes hung. In this case the hanging style is used with the view of making the shutter or door revolve more than a right angle, in order to turn it into a given position; as to bring a door close to a partition, to keep it out of the way.

HANGINGS, linings for rooms, made of arris, tapestry, or the like.

HANGS OVER, an expression used in speaking of a wall, when the top projects beyond the bottom.

HARD BODIES, such bodies as are absolutely inflexible to any shock or collision whatever.

This is the common meaning of the term; but Huygens, by hard bodies (*corpora dura*) meant what others call perfectly elastic bodies: for he thus expresses himself: "Quæcunque sit causa, corporibus duris, a mutuo contactu resiliendi cum se invicem impinguntur: ponimus, cum corpora duo inter se æqualia, æquali celeritate, ex adverso ac directe sibi mutuo occurrent, resilire utrumque eadem qua advenit celeritate." Huyg. *De Motu Corp. ex Percuss. Hypoth.* 2. But this hypothesis is consistent only with perfect elasticity, and not with the common supposition of hardness or inflexibility, which produces no resilition. The laws of motion for hard bodies are the same as for soft bodies, and these two sorts of bodies might be comprised under the common name of *unelastic.*

Some who follow Leibnitz's doctrine, concerning the measure of the moving force of bodies, deny the existence of hard or inflexible bodies. And it is so far true, that no experience ever taught us that there are any such. The hardest bodies to appearance do not preserve their figures in collision, such bodies being only elastic, yielding to the shock, and then restoring themselves.

M. Bernoulli goes so far as to say, that hardness, in the vulgar sense, is absolutely impossible, being contrary to the law of continuity. For supposing two such hard bodies of equal masses, and with equal velocities, to meet directly, they must either stop or return after the collision. The first supposition is commonly admitted; but then it follows, that these bodies must instantaneously pass from motion to rest, without going through successive diminutions of their velocities till they stop: but this is thought to be contrary to the fundamental laws of nature. Hence this author rejects perfectly solid and inflexible atoms, which others think a consequence of the impenetrability of matter.

HARD, a name given to a ford or passable place in a river particularly in and near the Fens, where many of these formerly occurred, composed of gravel, probably brought thither for the purpose. These HARDS proved very detrimental to navigation in dry seasons, and obstructed and augmented the floods in wet ones, until they were removed. Frequent mention is made of them by Mr. Smeaton, and by other writers on the navigation and drainage of those districts.

HARD FINISHING. *See* PLASTERING.

HARDENING OF TIMBER. *See* TIMBER.

HARMONIC or HARMONICAL PROPORTION, is when, in a series of quantities, any three adjoining terms being taken, the difference between the first and second is to the difference between the second and third as the first is to the third. The reciprocals of a series of numbers in arithmetical progression are in harmonical proportion: thus the reciprocals $\frac{1}{1}, \frac{1}{2}, \frac{1}{3}, \frac{1}{4}$, &c. of 1, 2, 3, 4, &c., are in harmonical proportion; also, the reciprocals $\frac{1}{1}, \frac{1}{3}, \frac{1}{5}, \frac{1}{7}$, &c., of 1, 3, 5, 7, &c. are harmonicals.

HARMONY, an agreement between all the parts of a building; the word is of similar import with SYMMETRY, which *see.*

HARNESS ROOM, a small apartment for keeping the harness in, that it may be preserved from mouldiness. The harness-room should be perfectly dry, and placed as near the stable as possible.

HASP, a fastening; it is in form a small clasp that passes over a staple to be fastened by a padlock.

HATCH-WAY, an aperture through the ceiling, to afford a passage to the roof.

HATCHET (from the French *hachette*) a small axe, used by joiners for reducing the edges of boards.

HAUNCH. That part of an arch between the vertex and the springing.

HEAD (from the Saxon) an ornament of sculpture of carved work, frequently serving as the key of an arch or platband.

These heads usually represent some of the heathen deities, virtues, seasons, or ages, with their attributes. The heads of beasts are also used in suitable places; as a bullock's or sheep's head, for a shambles or market-house; a dog's, for a kennel; a deer's or boar's, for a park or forest; or a horse's, for a stable.

In the metopes for the friezes and other antique Doric temples, we meet with representations of bullocks' or rams' heads flayed, as a symbol of the sacrifices offered there.

HEAD, *Jerkin*, *See* JERKIN HEAD.

HEADER. *See* HEADING COURSE.

HEADING COURSE, in masonry, a course of stones in which their length is inserted in the thickness of the wall; those with their length in the face of the wall are called *stretchers.* The same is also to be understood of brickwork.

HEADING JOINT, in joinery, the joint of two or more boards at right angles to the fibres; or, in hand-railing, at right

angles to the back; this is done with a view to continue the length of the board when too short. The heading-joints in good work are always ploughed and tongued, as in flooring, dado, &c. In dado, the heading-joints, besides being ploughed and tongued, are also glued.

Head-Way of a Stair, the clear distance, measured perpendicular to the horizon, from the tread of any step, resting-place, or landing, to the ceiling immediately above, in one revolution, making allowance for the thickness of the steps.

HEARSE or Herse, a metal frame sometimes set over effigies on tombs.

HEART-BOND, in masonry, the lapping of one stone over two others, which together make the breadth of the wall. This is practised when thorough-stones cannot be procured. *See* Masonry.

HEARTH. *See* Chimney.

HEATHER-ROOF, that kind of roof employed in building which is thatched over or covered with heather or heath, instead of some other material. It is recommended, as well adapted to buildings of the farm description, by the writer of the *Survey of the County of Argyle, in Scotland*, on the principle that it does well with timber of the ordinary sort, is capable of being procured for a trifle, lasts nearly as long as slates, and gives less trouble in the repair. It is asserted that a roof of this material, when well put on, will last one hundred years, provided the timber continues good that length of time. And it is stated, that formerly, most of the churches in the above county were covered with this sort of roof; likewise that heather-roofs are frequently met with in the district of Cowal, and that there are a few of them in Kintyre.

This sort of material may certainly be employed with advantage as a covering for small houses and other buildings, where other kinds of substances cannot be procured, except at a great expense; but at the same time it is very inferior to slate, and other similar matters, in forming the coverings of such erections.

HECATOMPEDON (from ἑκατον, a *hundred*, and πȣς *a foot*) a name given to the Parthenon, or temple of Minerva, at Athens.

HECATONSTYLON (ἑκατονςυλον) in ancient architecture, a portico with a hundred columns. This name was peculiar to the great Portico of Pompey's theatre at Rome.

HECK, a rack.

HEEL, in mouldings, the same as the sima-inversa.

Heel of a Rafter, the foot of the rafter, as it is formed to rest upon the wall-plate.

HEIGHT, the perpendicular distance of the most remote part of a body from the plane on which it rests.

HELICOID PARABOLA, or the Parabolic Spiral, a curve arising upon the supposition of the axis of the common Apollonian parabola being bent round into the periphery of a circle. The helicoid parabola, therefore, is a line passing through the extremities of the ordinates, which converge towards the centre of the said circle.

HELIOPOLIS, or The City of the Sun, in ancient geography, a city of Egypt, placed by geographers not far from Helle, at some distance from the eastern point of the Delta. It was built, according to Strabo, on a long artificial mount of earth, so as to be out of the reach of the inundation. This causeway, covered with rubbish, is still visible two leagues to the north-east of Grand Cairo, and three from the separation of the Nile. This city had a temple to the sun, where a particular place was set apart for the feeding of the sacred ox, which was there adored under the name of Menevis, as he was at Memphis under that of Apis. There was also in this city another magnificent temple, in the ancient Egyptian taste, with avenues of sphinxes and superb obelisks, before the principal entry. These temples were fallen into decay under the reign of Augustus; as the city had been laid waste with fire and sword by the fury of Cambyses. Of the four obelisks built by Sochis in that town, two were removed to Rome; another has been destroyed by the Arabs; and the last of them is still standing on its pedestal. It is composed of a block of Thebaic stone, perfectly polished, and is, without including its base, 68 feet high, and about $6\frac{1}{2}$ feet wide on each aspect. It is covered with hieroglyphics. This beautiful monument, and a sphinx of yellowish marble, overset in the mud, are the only remains of Heliopolis. *See* Egyptian Architecture.

HELIX, a term applied to the little scrolls in the Corinthian capital, called also *urillæ;* they are sixteen in number, viz. two at every angle, and two in the middle of the abacus, branching out of the caulicoli or stalks which rise between the leaves.

HELMET, a warlike ornament, in imitation of the helmet worn by the cavaliers, both in war and in tournaments, as a cover and defence of the head; the helmet is known by divers other names, as the *head-piece*, *steel-cap*, &c. The Germans call it *helen* or *hellem;* the Italians *elmo;* the French *casque*, as did also the ancient English.

The helmet covered the head and face, only leaving an aperture about the eyes, secured by bars, which served as a visor.

HEM, the protuberant part of the Ionic capital, formed by spirals.

HEMI, a word used in the composition of divers terms. It signifies the same with *semi* or *demi*, viz., *half;* being an abbreviation of ἡμισυς, *hemisys*, which signifies the same. The Greeks retrenched the last syllable of the word ἡμισυς in the composition of words; and, after their example, we have done so too, in most of the compounds borrowed from them.

HEMICYCLE, (Latin, *hemicyclium*, compounded of ἡμισυς, *half*, and κυκλος, *circle*) a semicircle. This word is particularly applied, in architecture, to vaults in the cradle form; and arches, or sweeps of vaults, constituting a perfect semicircle. To construct an arch of hewn stone, they divide the hemicycle into so many voussoirs; taking care to make them an uneven number, that there be no joint in the middle, where the key-stone should be.

HEMICYCLIUM, a part of the orchestra in the ancient theatre. Scaliger, however, observes, it was no standing part of the orchestra; being only used in dramatic pieces, where some person was supposed to be arrived from sea, as in Plautius's *Rudens*.

HEMISPHERE, (Latin, *hemispherium*, compounded of ἡμισυς, *half*, and σφαιρα, *sphere*) in geometry, one half of a globe, or sphere, when divided into two by a plane passing through its centre.

HEMISPHEROIDAL, a body approaching to the figure of a hemisphere, but not exactly so; of this description are what may be termed *elliptical domes*, upon either axis.

HEMITRIGLYPH, the half triglyph.

HENDECAGON, Endecagon, or Undecagon, (compounded of ἑνδεκα, *eleven*, and γωνια, *angle*) in geometry, a figure which has eleven sides, and as many angles. If each side of this figure be 1, its area will be equal to 9.3656399 $=\frac{11}{4}$ tangent $73\frac{7}{11}^{\circ}$, radius being 1.

HEPTAGON, (of ἑπτα, *septem*, *seven*, and γωνια, *angle*) in geometry, a figure consisting of seven sides and seven angles. If the sides and angles be all equal, it is called *a regular heptagon.* The area of a regular heptagon is equal to the square of one of its sides multiplied by 3.6339126.

HEPTAGONAL, consisting of seven angles, and therefore also of seven sides.

HERBOSUM MARMOR, a species of marble, much esteemed and used by the ancient architects and statuaries. It was of a beautiful green colour, but had always with it some cast of yellow. It was dug in the quarries of Taygetum, but was esteemed by the workmen the same in all respects, except colour, with the black marble dug at Tænarus in Lacædemonia, and thence called *Tænarian marble.*

HERRING-BONE, a term applied to a particular kind of masonry, in which the stones are laid aslant, inclining alternately right and left. Such work was common in Roman and Saxon structures.

HERMOGENES, the inventor of the eustyle intercolumniation; also of the octostyle pseudodipteros. He is mentioned by Vitruvius, chap. 2. book iii.

HEWN STONE, any stone when reduced to a given form by means of the mallet and chisel.

HEXAEDRON, or HEXAHEDRON (formed of ἑξ, *six*, and ἡδρα, *seat*) in geometry, one of the five regular bodies, popularly called *a cube. See* CUBE.

The square of the side of a hexaedron is in a subtriple ratio to the square of the diameter of the circumscribed sphere. Hence, the side of the hexaedron is to the diameter of the sphere in which it is inscribed, as one to the $\sqrt{3}$: and consequently it is incommensurable to it.

HEXAGON, (from ἑξ, *six*, and γωνια, *angle*) a figure of six angles, and consequently of six sides. If the angles and sides are equal, the figure is called a *regular hexagon.* If the side of a hexagon be denoted by s, its area will be $2.5980762\ s$.

HEXASTYLE, (from ἑξ, *six*, and ϛυλος, *column*) a building with six columns in front.

HINDOO ARCHITECTURE. *See* INDIAN ARCHITECTURE.

HINGES, metal ligaments, upon which doors, shutters, folds, lids, &c., turn in the act of opening and shutting.

There are many species of hinges, viz., butts, rising-hinges, pew-hinges, casement-hinges, casting-hinges, chest-hinges, coach-hinges, desk-hinges, dovetail-hinges, esses, folding-hinges, garnets, weighty side, side-hinges with rising joints, side-hinges with squares, screw-hinges, scuttle-hinges, shutter-hinges, trunk-hinges, of various descriptions, hook-and-eye-hinges, and centre-pin-hinges.

HINGING, a branch of joinery, which shows the art of hanging a board to the side of an aperture, so as to permit or exclude entrance at pleasure. The board which performs this office is called *a closure.* The placing of hinges depends entirely on the form of the joint, and as the motion of the closure is angular, and performed round a fixed line as an axis, the hinge must be so fixed that the motion may not be interrupted; thus if the joint contain the surfaces of two cylinders, the convex one in motion upon the edge of the closure, sliding upon the concave one at rest on the fixed body, the motion of the closure must be performed on the axis of the cylinder, which axis must be the centre of the hinges; in this case the joint will be close, whether the aperture be shut or open. But if the joint be a plane surface, it must be considered upon what side of the aperture the motion is to be performed, as the hinge must be placed on the side of the closure where it revolves.

The hinge is made in two parts, movable in any angular direction, one upon the other.

The knuckle of the hinge is a portion contained under a cylindric surface, and is common to both the moving part and the other part at rest; the cylinders are indented into each other, and made hollow to receive a concentric cylindric pin which passes through the hollow, and connects the moving parts together.

The axis of the cylindrical pin is called the *axis of the hinge.*

When two or more hinges are placed upon a closure, the axes of the hinges must be in the same straight line.

The straight line in which the axes of the hinges are placed is called the *line of hinges.*

The following are examples of the different cases.

The principle of hanging doors, shutters, or flaps, with hinges.

The centre of the hinge is generally put in the middle of the joint, as at A, *Figure* 1; but in many cases there is a necessity for throwing back the flap to a certain distance from the joint; in order to effect this, suppose the flap, when folded back, were required to be at a certain distance, as A B in *Figure* 2, from the joint; divide A B in two equal parts at the point C, which will give the centre of the hinge; the dotted lines B D E F, show the position when folded back.

Note.—The centre of the hinge must be placed a small degree beyond the surface of the closure, otherwise it will not fall freely back on the jamb or partition.

It must also be observed, that the centre of the hinge must be on that side that the rebate is on, otherwise it will not open without the joint being constructed in a particular form, as will be afterwards shown.

Figure 3 shows the same thing opened to a right angle.

To hang two flaps, so that when folded back, they shall be at a certain distance from each other.

This is easily accomplished by means of hinges having knees projecting to half that distance, as appears from *Figure* 4; this sort of hinges is used in hanging the doors of pews, in order to clear the moulding of the coping.

To make a rule joint for a window-shutter, or other folding-flaps.

Figure 5.—Let A be the place of the joint; draw A C at right angles to the flap, shutter, or door; take C, in the line A C, for the centre of the hinge; and the plain part A B, as may be thought necessary; on C, with a radius, C B, describe the arc B D; then will A B D be the true joint.

Note.—The knuckle of the hinge is always placed in the wood, because the farther it is inserted the more of the joint will be covered, when it is opened out to a right angle, as in *Figure* 6; but if the centre of the hinge were placed the least without the thickness of the wood, it would show an open space, which would be a defect in workmanship.

To form the joints of styles, to be hung together, when the knuckle of the hinge is placed on the contrary side of the rebate.

Figure 7.—Let C be the centre of the hinge, M I the joint on the same side of the hinge; K L the depth of the rebate in the middle of the thickness of the styles, perpendicular to K M, and L F the joint on the other side, parallel to K M; bisect K L at H, join H C; on H C describe a semicircle, C I H, cutting K M at I: through the points I and H, draw I H G, cutting F L at G; then will F G I M be the true joint; but if the rebate were made in the form of M K L F, neither of the styles could move round the joint or hinge.

To form the edges or joint of door-styles, to be hung to each other, so that the door may open to a right angle, and show a bead to correspond exactly to the knuckle of the hinge. Also the manner of constructing the hinges for the various forms of joints, so as to be let in equally upon each side.

Figure 8, No. 1, shows the edge of a style, or it may in some cases be a jamb, on which a bead is constructed exactly to the size of the knuckle of the hinge, and rebated backwards,

equal to half the thickness of the bead: the manner of constructing the rebate will be shown as follows:

Through C, the centre of the bead, which must also be the centre of the hinge, draw C B D perpendicular to E F; draw A G parallel to it, touching the bead at G; make G A equal to G C, the radius of the bead; join C A; make A B perpendicular to A C, cutting C D at B; then will G A B D be the joint required.

No. 2, shows a part of the hanging style constructed so as to receive the edge of No. 1.

No. 3, shows the above hinged together with common butt-hinges.

Note.—It must be observed in this, and all the following examples of hinges, that the joints are not made to fit exactly close, as sufficient space for the paint must be allowed.

Figure 9, No. 1 and 2. The manner of constructing these being only a plain joint at right angles to the face of the style, no farther description is necessary.

No. 3 shows No. 1 and 2 hinged together, and the particular construction of the hinge, so as to be seen as a part of the bead, and the strap of the hinge to be let equally into each style: this construction will admit of a bead of the same size exactly opposite to it.

Figure 10, No. 1 and 2. The manner of constructing the edges of styles to be hinged together with common butts, to be let equally into each style: the manner of constructing this joint is so plain, by the figure, that it would be useless to give any other description of it. No. 3, the two pieces hinged together.

Methods of jointing styles together so as to prevent seeing through the joints, each side of the styles to finish with beads of the same size, exactly opposite to each other, and for the strap of the hinges to be let equally into both parts or styles.

Figure 11, No. 1 and 2, the manner of constructing the joint before hinged together.

No. 3 shows No. 1 and 2 hinged together with common butts.

Figure 12, No. 1 and 2, shows another method of constructing the joints, before hinged together.

No. 3, shows No. 1 and 2 hinged, and the particular form of the hinges for the joint.

The principle of concealing hinges, showing the manner of making them, and of forming the joint of the hanging style, with the other style connected to it by the hinges, either for doors or windows.

Figure 13, for a window:

X, inside bead of the sash-frame.

Y, inside lining.

Z, style of the shutter.

Let A be the intersection of the face of the shutter, or door, with that of the inside lining of the sash-frame.

A R, the face of the inside lining.

Bisect the angle P A R by the right line A A; now the centre C being determined in A A at C, so that the knuckle of the hinge may be at a given distance from the face P A of the shutter; through C draw the line D D, at right angles to A A; then one side of the hinge must come to the line C D, the hinge being made as is shown by the figure.

To construct the jamb to be clear of the shutter.—

On C, as a centre, with a radius C A, describe an arc A M, and it will be the joint required.

Note.—When these sort of hinges are used in shutters, the strap of the hinge may be made longer on the inside lining, than that which is connected with the shutter.

Figure 14, is the manner of hanging a door on the same principle: the shadowed part must be cut out, so that the other strap of the hinge may revolve; the edge, C D, of the hinge, will come into the position of the line A A, when the window is shut in.

Here the strap part of the hinge may be of equal lengths.

Figure 15, the common method of hanging shutters together, the hinge being let the whole of its thickness into the shutter, and not into the sash-frame.

By this mode it is not so firmly hung, as when half is let into the shutter and half into the sash-frame, but the lining may be of thinner stuff.

Note.—It is proper to notice, that the centre of the hinge must be in the same plane with the face of the shutter, or beyond it, but not within the thickness.

Figure 16, the method of hanging a door with centres. Let A D be the thickness of the door and bisect it in B; draw B C perpendicular to A B; make B C equal to B A or B D; on C (the centre of the hinge) with a radius C A or C D, describe an arc, A E D, which will give the true joint for the edge of the door to revolve in.

HIP, in architecture, a piece of timber placed between every two adjacent inclined sides of a hip-roof, for the purpose of fixing the jack rafters. For the manner of finding the length and backing of the hips, *see* HIP-ROOF.

HIP-KNOB, a pinnacle, finial, or other ornament placed on the top of the hips of a roof, or on the apex of a gable, especially where barge-boards are employed.

HIP-MOULD, a mould by which the back of the hip-rafter is formed: it ought to be so constructed as to apply to the side of the hip, otherwise there will be no guide for its application.

HIP-ROOF, a roof whose ends rise immediately from the wall-plate, with the same inclination to the horizon as the other two sides of the roof have.

The backing of a hip is the angle made on its upper edge, to range with the two sides or planes of the roof between which it is placed.

Jack-rafters are those short rafters fixed to hips equidistantly disposed in the planes of the sides and ends of the roof, and parallel to the common rafters, to fill up the triangular spaces, each of which is contained by a hip-rafter, the adjoining common rafter, and the wall-plate, between them. The seat or base of the rafter is its ichnographic projection on the plane of the wall-head, or on any other horizontal plane.

The principal angles concerned in hip-roofing are, the angle which a common rafter makes with its seat on the plane of the wall-head; the vertical angle of the roof; the angle which a hip makes with the adjoining common rafter; the angles which a hip makes with the wall-plate on both sides of it; the angle which a hip-rafter makes with its seat; and the acute angle which a hip-rafter makes with a vertical line. The principal lengths concerned are, the height of the roof; the length of the common rafters and their seats; the length of the hips and their seats; and, lastly, the length of the wall-plate contained between the lower end of a hip and the lower end of the adjacent common rafter.

The sides and angles may be found by geometrical construction or trigonometrical calculation. It is evident, that if the hipped end of a roof be cut off by a vertical plane parallel to the wall, through the upper extremity of the hips, it will form a rectangular pyramid, or one whose base is a rectangle. The base of this pyramid is bounded by the wall-plate between the two hips on one side, and on the opposite side by the seat of the two adjoining common rafters; on the other two opposite sides, by that part of the wall-plate on each side contained by the lower end of the hip and the next common rafter adjoining. One of the sides is the isosceles triangle contained by the two adjoining common rafters with their seat; the opposite side is the hipped end of the roof, forming

also an isosceles triangle; the other two opposite sides are the right-angled triangles contained by the two hips and the two adjoining rafters on the side of the roof. This rectangular pyramid may be divided into three triangular pyramids by the two vertical triangular planes, formed by the hip-rafters, their seats, and the common perpendicular from their vertex.

Two of these pyramids, when the plan of the building is a rectangle, are equal and opposite. In each of these equal and opposite pyramids the base is a right-angled triangle, contained by the seat of the hip-rafter, the seat of the adjoining common rafter, and the part of the wall-plate between the hip and the adjoining common rafter. One of the sides is a right-angled triangle contained by the adjoining common rafter, its seat, and perpendicular: a second side is a right-angled triangle contained by the common rafter, the hip-rafters, and the wall-plate, between them; and the remaining third side is the triangle contained by the hip-rafter, its seat, and perpendicular. With regard to the remaining pyramid, its base is a right-angled triangle contained by the seats of the two hips and the wall-plate between them, the right angle being that contained by the seats of the two hips; two of its sides are the triangular planes passing the hip-rafter, which are also common to the other two pyramids; its third side is the hipped end of the roof.

Given the plan of a building, or the form of a wall-plate of a hip-roof, and the pitch of the roof, to find the various lengths and angles concerned, whether the roof is square or bevel.

EXAMPLE I.—*To find the length of the rafters, the backing of the hips, and the shoulders of jack-rafters and purlins, geometrically.*

Plate I.—*Figure* I.—Let A B C D be the plan. Draw E F parallel to the sides, A D and B C, in the middle of the distance between them. On D C, as a diameter, describe the semicircle D F C: draw F D and F C, then the angle D F C is a right angle. Draw G F H perpendicular to E F, cutting the sides A D and B C in G and H; from F E cut off F I equal to the height or pitch of the roof, and join G I; from F C cut off F K equal to F I, and join K D; then G I is the length of a common rafter, and D K that of the hip; for if the triangles G F I and D F K be turned round their seats, G F and D F, until their planes become perpendicular to the triangle G F D, the perpendicular F I will coincide with F K, and the point I will coincide with the point K; the lines G I and D K, representing the rafters, will then be in their true position.

The same by calculation. $GI^2 = GF_2 + FI^2$ (Euclid i. 47.) therefore, $GI = (GF^2 + FI^2)\frac{1}{2}$ the length of the common rafter, $DF^2 = GF^2 + GD^2$ the square of the seat of the hip. $DK^2 = DF^2 + FK^2 = GF^2 + GD^2 + FI^2$, therefore $DK = \overline{GF^2 + GD^2 + FI^2}^{\frac{1}{2}}$.

In the same manner the other hip-rafter C L is found, as also the hip-rafters A M and B N.

Let it be required to find the backing of the hip-rafter whose seat is C F.

Geometrically.—Imagine the triangle C F L to be raised upon its seat C F, until its plane becomes perpendicular to the plane of the wall-plate A B C D, then there will be two right-angled solid angles; the three sides of the one are the plane angles of F C D, F C L, and the hypothenusal plane angle D C L. In each of these solid angles the two sides, containing the right angle, viz., the plane angles F C H, F C D, and the perpendicular plane angle C F L, which is common to both, being given to find the two opposite inclinations to the sides F C H and F C D, and the remaining third sides.

Now the angles G D C and H C D are besected by the seats F D and F C of the hip-rafters; for if E F is produced to meet D C in U, U will be the centre of the circle D F C; and U C, U F, U D, are equal to each other; and because U F is equal to U C, the angle C F U is equal to F C U; but C F U is equal to the alternate angle F C H; therefore, the angle F C U is equal to F C H; that is, the angle U C H is besected by the seat F C of the hip-rafter. In the same manner may be shown that U D G is besected by the seat D F of the other hip-rafter. From any point, O, in F C, draw O V perpendicular to L C, cutting it in P, and O W perpendicular to F C, cutting D C in W; from O C cut off O Q equal to O P. Join Q W, then O Q W will be the inclination opposite the plane angle F C U, and this is the angle which the end of the roof makes with the vertical triangle contained by the hip-rafter, its seat, and perpendicular. Produce W O to meet B C in X, and join Q X, then W Q X is the inclination of the two planes of a side and end of the roof, whose intersections are B C and C D, on the plane of the wall-head. Now, the angle W Q X, which is double the angle W Q O, is the backing of the hip. Make P V equal to Q W, and join C V, then will P C V be the angle contained by the two sides L C, C D, or that of the hypothenusal plane angle contained by the intersection B C, and the hip-rafter L C. This angle may be otherwise found thus:—Produce G H to R; make C R equal to C L, then the angle H C R is equal to P C V. Now the angle H C R, or P C V, is the angle which the purlins (when one of their faces is in the side of the roof) make with the hip-rafter L C; and the angle C V P, or C R H, is the angle which a jack-rafter makes with the same hip; in the same manner may the backings of the other hips be found. The other bevel of the jack-rafters is the angle H I F. To find the other bevel for cutting the shoulder of the purlin, proceed thus: on F, as a centre, with the distance F G, describe the arc G Y; draw F Y perpendicular to G I, Y Z parallel to E F, cutting F D in Z, and Z & parallel to G H, cutting A D in &. Join & F, then G & F is the angle which the other side of the shoulder makes with the length of the purlin.

At the other end of this diagram is shown the manner of finding the two bevels for cutting the shoulder of the purlin against the hip-rafter when the side of the purlin is not in the plane of the side of the roof.

To find the same things by calculation.—The backing of the hip-rafter and hypothenusal side is obtained as follows:—It has been shown that the three plane angles, and the three inclinations of solid angles, consisting of three plane angles, are found exactly as the sides and angles of spheric triangles, any three parts being given; the degrees of the plane angles being exactly the same as the sides of the spheric triangles, and the inclinations the proper measures of the spheric angles; therefore, if two of the plane angles should be perpendicular to each other, the spheric triangle representing this solid angle will have also two of its sides perpendicular to each other. Now, in this, there are given the two sides containing the right angle to find the hypothenuse and angles.

It is shown, by writers on spherical trigonometry, that in any right-angled spherical triangle, radius is to the cosine of either of the sides, as the cosine of the other side to the cosine of the hypothenuse. Suppose the plane angle F C L to be 27°, and the angle F C H 52°, to find the hypothenuse and angles of a right-angled spherical triangle, one of whose legs is 27° and the other 52°, it will therefore be—

As radius, sine of 90° . . . . =	10.00000
Is to the cosine of F C L, 27° . . . . . =	9.94988
So is the cosine of F C H 52° . . . . . =	9.78934
	19,73922
	10.00000
To the cosine of the hypothenusal side 56° 44′	9.73922

This ascertains the angle which the jack-rafter makes with the hip. Since all the sides are now given, we shall have, by another well-known property, of the sines of the sides being as the sides of the opposite angles, the following proportion :—

As the sine of the hypothenuse 56° 44′ . .	=	9.92227
Is to the sine of a right angle, or 90° . . .	=	10.00000
So is the sine of the side F C H, 52° . . .	=	9.89653
		10.89753
		9.92227
To the sine of the opposite angle 70° 28′ . . .	=	9.97426
Therefore the backing is twice 70° 28′ . . .	=	140° 56′

In finding the angle opposite the side F C H, it was not necessary that the hypothenusal side should have first been found. It might have been found independently thus :—The sine of either of the sides about the right angle is to radius, as the tangent of the remaining side is to the tangent of the angle opposite to that side ; therefore,

As the sine of the side F C L, 27°	=	9.65705
Is to the tangent of the side F C H 52° . .	=	10.10719
So is radius, sine of 90°	=	10.00000
		20.10719
		9.65705
To the tangent of the angle opposite the side F C H, 70° 28′	=	10.45014

In the same manner may other bevels be found by trigonometrical calculations; but as such extreme exactness is not necessary, the geometrical constructions ought to be well understood.

EXAMPLE II.—*The figure* A B C D (*Figure* 2) *of the wall plate of a hip span-roof, and the height of the roof being given; to find the backing of the hips, the angles made upon the sides of the purlins by their longitudinal arrises, and the angles made upon the sides of the jack-rafters; the roof being equally inclined to the different sides of the building, except at the oblique end*, A B.

Figure 2.—Let the two sides, A B, A D, and D C of the wall-plate be at right angles to each other, and the end C B at oblique angles to A B and C D; draw the seat, E F, of the ridge in the middle of the breadth, parallel to A B and D C ; make A G and D H equal to half the breadth of the building ; join G. H, which will be the seat of the common rafters adjoining the hips ; make E I equal to the height of the roof; and draw I G and I H, which are the length of the common rafters. Draw E D and E A, the seats of the hips ; make E K equal to E I; and draw K A, which gives the length of each hip. Through any point, L, in the seat of the hip A E, draw M N perpendicular to A E, cutting the adjacent sides of the wall-plate at M and N; take the nearest distance from L to the rafter A K, and make L O equal to it; and draw O M and O N; and M O N is the backing of the hips, represented by their seats A E and D E.

This operation is the same as having the two legs of a right-angled solid angle to find the angle opposite to one of the legs; the angle M O N being exactly the double of the angle so found; for the hip angle of the roof consists of two equal solid angles.

Suppose the bevel end at C B to be inclined at a different angle to the other sides, and let F C and F B be the seats of the hips; draw F Q perpendicular to F C, and F P perpendicular to F B, each equal to the height of the roof; then draw Q C and P B, which are the lengths of the hip-rafters.

The backings S U T and V W X, are found in the same manner as above, and may be described in the same words.

From A, with the distance A K, describe an arc cutting G H at J, and join A J; then G J A will be the side bevel, which the jack-rafters make with the hips; and if a right angle be added to G J A, it will form an obtuse angle, which is that made by the upper arris of the side of a purlin placed in the inclined side of the roof with the hip-rafter.

Let *a* be the position of a purlin in the rafter H I; in G H take any point, *b*, and draw *b c* parallel to the inward direction of the purlin *a;* from *b*, with any distance, *b c*, describe an arc *c d*, cutting G H at *d;* draw *b e*, *c f*, and *d g*, parallel to E F; the former two cutting E D at *e* and *f;* draw *f g* parallel to G H, and join *e g;* produce *b e* to *h;* and *h e g*, or *b e g* will be the angle required, according to which side it is applied: this will be found synonymous to one of the legs, and the adjacent angle of a right-angled solid angle being given, to find the hypothenuse. In the same manner, if neither side of the purlin should be parallel to the inclined side of the roof, as at *k* in the rafter G I, the bevel or angle upon each side may be found, as shown.

Plate II.—*Figure* 3, shows half the angle of the backing of the hips, the length of the common and hip-rafters, the bevel of the jack-rafters on their upper sides in an equal inclined roof, without laying down or drawing any more than the necessary seats; and this is all that is necessary when each side of the roof is alike; A B being the wall-plate between the hip and the rafter which joins the top of the hip, A C the seat of the rafter which joins the top of the hip, B C that of the hip, A F the length of the rafter which joins the hip, B E the length of the hips, C H G half the backing, A D B the angle which the jack-rafters form with the upper sides of the hips, and, consequently, with the addition of a right-angle, the side bevel of the purlin.

Figure 4, shows the same bevels, except that the side joint of the purlin is found by a different process, thus: from B, with the distance B A, describe an arc at D; from G, with the distance A C, describe another arc, cutting the former at D; join B D, and the angle G B D will be the angle in the plane of the roof, made by the lower arris of the purlin and the joint against the hip-rafter.

Besides the angles already mentioned, A F C *Figure* 3, shows the angle formed by the upper side of the rafter and the ridge-piece, and the angle B E C, the angle which the top side of the hips makes with a vertical or plumb-line; also the angle F A C shows the form of the heel of the common rafters, and E B C that of the hips.

Figure 5, is a diagram showing the length of the parts and angles concerned in the roof, in the same manner as above; but the plan of the building, or form of the wall-plate, is a quadrilateral, which has neither part of its opposite sides parallel; the method of executing the roof in this case is to form a level on the top, from the top of the hips at the narrow end to the other extremity, as otherwise the roof must either wind, or be brought to a ridge forming a line inclined to the horizon; and either of the two last cases is very unsightly. But, that nothing should be wanting, the construction is given in the next figure.

Plate III.—*Figure* 6.—*To lay out an irregular roof in ledgment, with all its beams bevel upon the plan, so that the ridge may be level when finished ; the plan and height of the roof being given.*

The length of the common and hip-rafters are found as usual. From each side in the broadest end of the roof, through C and D, draw two lines parallel to the ridge-line

draw lines from the centres and ends of the beams, perpendicular to the ridge-line, and lay out the two sides of the roof 2 and 3, by making E D at 3 equal to X N in 1, the length of the longest common rafter, and *c a* in 3 equal to *u &* at A, and so on with all the other rafters.

To find the winding of this roof.—Take *y &*, half the base of the shortest rafter, and apply this to the base of the longest rafter from *z* to 1; then the distance from 1 to 2 shows the quantity of winding.

To lay the sides in winding.—Lay a straight beam along the top ends of the rafters at E, that is, from *c* to E, and lay another beam along the line A B, parallel to it, to take the ends of the hip-rafters at M and L, and the beams to be made out of winding at first. Raise the beam that lies from *a* to B, at the point B, to the distance 1 2 above the level; which beam, being thus raised, will elevate all the ends of the rafters gradually, the same as they would be when in their places.

The same is to be understood of the other side D; the ends are laid down in the same manner as in making a triangle of any three dimensions.

In this example, the purlins are supposed to be framed into the sides of the rafters flush, so that the lop of the purlins may be flush with the back of the rafters. The manner of framing the dragon beams and diagonal ties, is shown at the angles.

Plate IV.—*Figure* 7, shows the manner of framing a roof when the sides are square. The purlins are prepared to bridge over the rafters, which are notched out of the sides next to the back, in order to receive them.

HIPPIUM, in antiquity, that part of the hippodrome which was beaten by the horses' feet.

HIPPODROME, (from the Latin, *hippodromus*, composed of ἱππος, *horse*, and δρομος, *course*, of the verb δρεμω, *curro*, *I run*,) in antiquity, a list, or course, wherein chariot and horse-races were performed, and horses exercised.

The Olympian hippodrome, or horse-course, was a space of ground 600 paces long, surrounded with a wall, near the city Elis, and on the banks of the river Alpheus. It was uneven and in some degree irregular, on account of the situation; in one part was a hill of moderate height, and the circuit was adorned with temples, altars, and other embellishments. Pausanias has given us the following account of this hippodrome, or horse-course:—"As you pass out of the stadium, by the seat of the Hellanodics, into the place appointed for the horse-races, you come to the barrier (αφεςις) where the horses and chariots rendezvous before they enter into the course. This barrier, in its figure, resembles the prow of a ship, with the rostrum or beak turned towards the course. The other end, which joins on to the portico of Agaptus, (so called from him who built it) is very broad. At the extremity of the rostrum or beak, over a bar that runs across the entrance (επι κανονος,) is placed a figure of a dolphin in brass. (This dolphin is a symbol of Neptune, surnamed Hippian or Equestrian, for his having produced a horse by striking the earth with his trident, according to the fable; without the recollection of this circumstance, the reader might be surprised to meet with the figure of a dolphin in a horse-course.) On the two sides of the barrier, each of which is above 400 feet in length, are built stands or lodges, as well for the riding-horses as the chariots, which are distributed by lot among the competitors in those races; and before all these lodges is stretched a cable, from one end to the other, to serve the purpose of a barrier. About the middle of the prow is erected an altar, built of unburnt brick, which, every Olympiad, is plastered over with fresh mortar; and upon the altar stands a brazen eagle, which spreads out its wings to a great length. This eagle, by means of a machine, which is put in motion by the president of the horse-races, is made to mount up at once to such a height in the air, as to become visible to all the spectators; and, at the same time, the brazen dolphin before mentioned sinks to the ground. Upon that signal, the cables stretched before the lodges, on either side of the portico of Agaptus, are first let loose, and the horses there stationed move out and advance, till they come over against the lodges of those who drew the second lot, which are then likewise opened. The same order is observed by all the rest, and in this manner they proceed through the beak or rostrum; before which they are drawn up in one line, or front, ready to begin the race, and make trial of the skill of the charioteers and fleetness of the horses. On that side of the course, which is formed by a terrace raised with earth, and which is the largest of the two sides, near to the passage that leads out of the course across the terrace, stands an altar, of a round figure, dedicated to Taraxippus, the terror of the horses, as his name imports. The other side of the course is formed, not by a terrace of earth, but a hill of moderate height, at the end of which is erected a temple, consecrated to Ceres Chamyne, whose priestess has the privilege of seeing the Olympic games."

There is a very famous hippodrome at Constantinople, which was begun by Alexander Severus, and finished by Constantine. This circus, called by the Turks *Atmeidan*, is 400 paces long, and above 100 paces wide, *i. e.* geometrical paces of five feet each. Wheeler says, it was in length about 550 ordinary paces, and in breadth about 120; or, allowing each pace to be five feet, 2,750 feet long and 600 broad. At the entrance of the hippodrome there is a pyramidal obelisk of granite, in one piece, about 50 feet high, terminating in a point, and charged with hieroglyphics, erected on a pedestal of eight or ten feet above the ground. The Greek and Latin inscriptions on its base show that it was erected by Theodosius; the machines that were employed to raise it were represented upon it in basso-relievo.

The beauty of the hippodrome at Constantinople has been long since defaced by the rude hands of the Turkish conquerors; but, under the similar appellation of *Atmeidan*, it still serves as a place of exercise for their horses. Whether the Olympic hippodrome was so long or so wide as this of Constantinople, it is not now easy to determine; but it must evidently have been considerably longer than an ordinary stadium, in order to allow for the turnings of the chariots and horses round the pillars which served as metas or goals, without running against them, or against one another. The length of the course, or the distances between the two metas or goals, is not easily ascertained. It is probable, however, that the two pillars, *viz.*, that from which the horses started, and that round which they turned, which divided the course into two equal lengths, were two stadia distant from each other; consequently, the whole length of the race, for a chariot drawn by full-aged horses, consisting of 12 rounds, amounted to 48 stadia, or six Grecian miles; and that of the chariot drawn by colts consisted of eight rounds, or 32 stadia, or four Grecian miles—a Grecian mile, according to Arbuthnot's computation, being somewhat more than 800 paces, whereas an English mile is equal to 1,056. Pausanias informs us, that in the Olympic hippodrome, near that pillar called Nyssé, probably that which was erected at the lower end of the course, stood a brazen statue of Hippodamia, holding in her hand a sacred fillet or diadem, prepared to bind the head of Pelops for his victory over Œnomaus; and it is probable that the whole space between the pillars was filled with statues or altars, as that in the hippodrome at Constantinople seems to have been. Here, however, stood

the tripod, or table, on which were placed the olive-crowns and the branches of palm destined for the victors. Besides the hippodromes at Olympia and Constantinople, there were courses of a similar kind at Carthage, Alexandria in Egypt, and other places.

We have some vestiges in England of the hippodrome, in which the ancient inhabitants of this country performed their races. The most remarkable is that near Stonehenge, which is a long tract of ground, about 350 feet, or 200 druid cubits wide, and more than a mile and three-quarters, or 6,000 druid cubits in length, enclosed quite round with a bank of earth, extending directly east and west. The goal and career are at the east end. The goal is a high bank of earth, raised with a slope inwards, on which the judges are supposed to have sat. The metæ are two tumuli, or small barrows, at the west end of the course. These hippodromes were called, in the language of the country, *rhedagua*, the racer *rhedagwr*, and the carriage *rheda*, from the British word *rhedeg*, *to run.* One of these hippodromes, about half a mile to the southward of Leicester, retains evident traces of the old name *rhedagua*, in the corrupted one of *rawdikes.* There is another of these, says Dr. Stukely, near Dorchester, another on the banks of the river Lowther, near Penryth, in Cumberland, and another in the valley just without the town of Royston.

HISTORICAL COLUMNS. *See* Column.

HOARDING, (from the Saxon,) an enclosure about a building, while erecting or under repair.

HOIST, an apparatus, or lift, for raising bodies from a lower to an upper story in a building.

HOLLOW, (from *hole*,) a concave moulding, whose section is about the quadrant of a circle. It is, by some writers, called *easement.*

Hollow Bricks, a kind of brick recently invented, moulded of various sizes and shapes, but usually of larger size than those commonly in use. They are mere shells, as it were, the heart of the brick being removed. The advantages claimed for such bricks are their superior strength when considered with reference to the quantity of material; and as a consequence, their comparative lightness, a quality which tells in very many ways. In the manufacture, they are more evenly baked and dried, the heat being equally distributed over every part; and hence their texture and hardness are more to be depended upon than in solid bricks. When used for houses, there is much less fear of damp than in new work as at present constructed; and an equability of temperature is ensured in the interior. Sound also is much less easily communicated by them than by common bricks. It has been proposed to construct them with grooves and ledges, or with some similar contrivance, so that they may be fitted compactly together in a short space of time, for temporary or other purposes. Floors also are proposed to be constructed of the same materials, so as to render buildings entirely fire-proof.

Hollow Newel, an opening in the middle of a staircase. The term is used in contradistinction to *solid newel*, into which the ends of the steps are built. In the hollow newel, or well-hole, the steps are only supported at one end by the surrounding wall of the staircase, the ends next the hollow being unsupported.

Hollow Wall, a wall built in two thicknesses, having a cavity between, either for the purpose of saving materials, or to preserve a uniform temperature in the apartments.

Hollow Quoins, in engineering, piers of stone or large bricks, made behind each lock-gate of a canal, which are formed into a hollow from top to bottom, to receive the rounded head of the lock-gates. In some instances the hollow quoin is formed of one piece of oak, cut to the proper shape, and fixed vertically against the wall. Cast-iron is also now frequently used for forming the hollow quoin or hinge for the lock-gates of large canals, or the entrance-basons to docks.

HOMESTALL, or HOMESTEAD, the place of a mansion-house; the word is used in some countries to signify the original house or dwelling attached to an estate.

HOMOLOGOUS, (from ὁμυος, *similar*, λογος, *reason*,) in geometry, the correspondent sides of similar figures.

HOOD-MOULD, a band or string carried over any aperture, such as a door or window; more particularly employed in Pointed architecture: the term is synonymous with Label and Weather Moulding.

HOOK PINS, in carpentry, iron pins made tapering towards one end, for the purpose of drawing the pieces of a frame together, as in floors, roofs, &c. In joinery, the pins which answer a similar purpose are called Draw-Bore Pins.

HOOKS, (Saxon) bent pieces of iron, used to fasten bodies together, or to hang articles on, out of the way. They are of various kinds, some of iron and some of brass; as casement-hooks, chimney-hooks, which are made of both brass and iron; curtain-hooks, hooks for doors and gates, double-line-hooks, tenter-hooks, armour-hooks, &c.

HORDING. *See* Hoarding.

HORIZONTAL CORNICE, of a pediment, the level part under the two inclined cornices.

Horizontal Line, in perspective, the vanishing lines of planes parallel to the horizon.

Horizontal Plane, a plane passing through the eye, parallel to the horizon, and producing the vanishing line of all level planes.

Horizontal Projection, the projection made on a plane parallel to the horizon. This may be understood either perspectively or orthographically, according as the projecting rays are directed to a given point, or are perpendicular to the horizon.

HORN, (Saxon) a name sometimes applied to the Ionic volute.

HORSE PATH, in engineering, a name sometimes applied to the towing-path by the side of canals, and narrow navigable rivers, for the use of the towing or track horses.

Horse Run, in engineering, a simple and useful modern contrivance, for drawing up loaded wheel-barrows of soil from the deep cuttings of canals, docks, &c. by the help of a horse which goes backwards and forwards, instead of round, as in a horse-gin.

HORSING BLOCK, a square frame of strong boards, used by navvigators or canal diggers for elevating the ends of their wheeling planks.

HOSPITAL. According to present usage, the term is applied to buildings endowed by public or private charity, as infirmaries, in which invalids are lodged and attended; but in olden times the term was used to signify any building erected for charitable purposes, as for the relief of the indigent, the entertainment of travellers, &c.

HOSTEL, or Hotel, a French term, anciently signifying a house, but now more commonly used for the palaces or houses of the king, princes, dukes, and great lords. The word is also applied to large inns, taverns, or places of public entertainment.

HOT-HOUSE, in horticulture, is a structure in which exotic plants are cultivated, under circumstances approximating, as closely as possible, to those under which they naturally exist; or it is used for accelerating the production of flowers and fruits of either indigenous or exotic plants. Hot-houses appropriated to the latter purposes are very frequently termed *forcing-houses.*

In the beginning of the seventeenth century, that description of hot-house generally termed the *green-house* began to be constructed in Germany; and one in the Apothecaries' Garden at Chelsea is mentioned by Ray in 1684. These, like many others of a later construction, had glass only in the front, which was perpendicular; and the mode of applying artificial heat exhibited little more knowledge of means for the end, than the remains of flues found in the ruins of the dwelling-houses and baths of the Romans.

In 1724, when Switzer published his treatise entitled "The Practical Fruit Gardener," the principles of managing hot-houses were still very imperfectly understood; for he observes, p. 305, that "peaches, nectarines, and apricots don't love to be forced; at least, the fruit is very seldom good: there being much occasion to keep the glasses close, the fruit is always rendered flat and insipid. This is not pure speculation, but the result of the practice that I have observed in the glass-houses at Brompton Park."

Considerable alterations, particularly in houses for grapes, were made towards the end of the last century. The most material improvement was the substitution of a slanting glass roof for a perpendicular glass front; but the advantages of this were much diminished by the heaviness of the sashes, and the large quantity of opaque matter which it was thought necessary to employ in order to ensure the durability of such structures.

In the present century great advances have been made in hot-house building, and more particularly since 1815. The application of heat by steam or hot water through iron pipes, and the admission of a greater quantity of light by glazing on metallic bars, instead of wooden sashes, are the principal features of these improvements. The employment of hollow bricks, too, will probably prove of great advantage, although we are not aware of their adoption in any building at present erected. *See* CONSERVATORY.

Those houses which are intended for the peach, nectarine, cherry, fig, &c. should in cold situations, be constructed against walls, and made with glass on one side. But in climates less severe, houses formed of glass on all the sides, having the trees so planted as to grow irregularly in the standard method, will be more beneficial as well as more ornamental.

For the forcing of vines, they may be of any kind of form, either small or large, according to the season at which the trees are to be brought into fruit. But a double-roofed house, with an inner roofing, is recommended as the most proper for general crops, as well as the cheapest in cost of erecting.

In the general construction of these houses, a wall of eight or ten feet in height, or more, is raised behind, with a low wall in front and both ends, on which is placed upright glass-work, four, five, or six feet in height, and a sloping glass roof, extending from the top of the front to the back wall. Internal flues for fire-heat, in winter, are also contrived, and a capacious oblong or square pit in the bottom space, in which to have a constant bark-bed, to furnish a continual regular heat at all seasons; so as in the whole to warm the enclosed internal air always to a certain temperature. Houses thus formed are generally used in raising pines.

Hot-houses are mostly ranged lengthwise, nearly east and west, that the glasses of the front and roof may have the full influence of the sun. This is the most convenient situation for common houses, either for pines or exotic plants. But some houses of the sort, instead of being placed in this direction, are ranged directly south and north, having a sloped roof to each side, like the roof of a house; as also to the front or south end; both sides and the south-end front being of glass. These houses are made from ten or twelve to fifteen or twenty feet wide, the length at pleasure; and from ten to twelve feet high in the middle, both sides fully head-height; being formed by a brick wall all round, raised only two or three feet on both sides, and south end; but carried up at the north end like the gable of a house. Upon the top of the side and south-end walling is erected the framing for the glass-work, which is sometimes formed two or three feet upright, immediately on the top of the wall, having the sloped glass-work above; and sometimes wholly of a continued slope on both sides, rising immediately from the top of the side-walls to that of the middle ridge. They are furnished either with one or two bark-pits; but if of any considerable width, generally with two, ranging parallel, one under each slope of the top glass, and separated by a two-foot path running along the middle of the house, and sometimes continued all round each pit, with flues ranged along against the inside walls; the whole terminating in an upright funnel, or chimney, at the north end of the building. There are other hot-houses which are formed entirely on the square, having a ten or twelve feet brick wall behind; that of the front, and both sides, being only two or three feet high, for the support of the glass-work, which is placed nearly upright almost the same height, and sloped above on both sides and front, which are wholly of glass. These are furnished within with bark-pits and flues, as in the previous instances.

In particular cases they are made semicircular, or entirely circular, being formed with a two or three feet brick wall supporting the glass-framing, which is continued quite round. The bark-pit is also circular, and the flues, after being carried all round the inside of the walling, terminate in a chimney on the northern side of the house. However, the first forms are probably the best for general purposes.

Hothouses on these plans are made of different dimensions, according to the size of the plants they are designed to contain. For common purposes they should be only of a moderate height, not exceeding ten or twelve to fourteen feet behind, and five or six in front; some are, however, built much more lofty behind, to give sufficient height for the taller-growing exotics, placed toward the back part. Those of the first-described size are, however, best adapted to the culture of pines, and other moderate-growing plants, as well as for forcing in. Very lofty houses require a greater force of heat, and by the glasses being so high, the plants naturally tending towards the glasses, receive less benefit from the sun and are apt to draw up too fast into long slender leaves and stems. Where the top-glasses are at a moderate distance from the plants, they receive the benefit of the sun's heat more fully, which is essential in winter, become more stalky at bottom, assume (particularly the pine-apple) a more robust and firm growth, and are rendered more capable of producing large fruit in the season.

After having determined on the dimensions of the house as to length and width, the foundations of brick-work should be set out accordingly, allowing due width at the bottom to support the flues a foot wide, wholly on the brick basis; detached an inch or two from the main walls; then setting off the back or north-wall, a brick and a half or two bricks thick, and the front and end walls nine inches, carry up the back wall from ten to fourteen feet high; those of the front and ends to be only from about two feet to a yard. Take care in carrying up the walls to allot a proper space for a door-way, at one or both ends, towards the back part; setting out also the furnace or fire-place of the flues in the bottom foundation towards one end of the back wall behind, formed also of brick-work, made to communicate with the lowermost flue within. When the house is of great length, as forty feet or more, a fire-place at each end may be necessary; or, if more

convenient, both may be in the back part of the end walls, or in the middle way of the back wall; each must communicate with a separate range of flues. In either case they should be formed wholly on the outside of the walls, about twelve or fourteen inches wide in the clear, but more in lengthwise inward; the inner end terminating in a funnel to communicate internally with the flues. An iron-barred grate should be fixed at bottom to support the fuel, and calculated for coal, wood, peat, turf, &c. An ash-hole should be made underneath. The mouth or fuel-door should be about ten or twelve inches square, having an iron frame and door fixed to shut with an iron latch, as close as possible. The whole furnace should be raised sixteen or eighteen inches in the clear, finishing the top archwise. Then continue carrying up the walls of the building regularly, and on the inside erect the flues close along the walls.

It is sometimes advantageous to have the flues a little detached from the walls, one, two, or three inches, that, by being thus distinct, the heat may arise from both sides, which will be an advantage in more effectually diffusing the whole heat internally in the house; as, when they are attached close to the walls, a very considerable portion of the heat is lost in the part of the wall behind. In contriving the flues, they should be continued along the front and both ends, in one range at least, in this order. But it is better if they are raised as high as the outward front and end walls, in one or two ranges, one over the other. On the tops of these may be placed pots of many small plants, both of the exotic and forcing kinds, with much convenience.

In the construction of the flues, make them generally about a foot wide in the whole, including six or eight inches in the clear, formed with a brick-work on edge; the first lower flue should communicate with the furnace or fire-place without, and be raised a little above it, to promote the draught of heat more freely. Continue it along above the internal level of the floor of the back alley or walk of the house the above width, and three bricks on edge deep, returning it in two or three ranges over one another, next the back wall, and in one or two along the ends and front wall, as the height may admit; each return two bricks on edge deep, and tiled or bricked over. In the beginning of the first bottom-flue a sliding iron regulator may be fixed, to use occasionally, in admitting more or less heat, being careful that the brick-work of each flue is closely jointed with the best sort of mortar for that purpose, and well pointed within, that no smoke may break out. Have each return closely covered with broad square paving tiles on the brick-work; covering the uppermost flues also with broad thick flat tiles, the whole width, all very closely laid, and joined in mortar. The uppermost, or last range of flues, should terminate in an upright vent or chimney, at one end of the back wall; and where there are two separate sets of flues, there should be a chimney at each end. An iron slider in the termination of the last flue next the chimney may also be provided, to confine the heat more or less on particular occasions, as may be found necessary.

Sometimes, in very wide houses, in erecting the flues, spare ones, for occasional use, are continued round the bark-pit, carried up against the surrounding wall, but detached an inch or two, to form a vacancy for the heat to come up more beneficially, and that, by having vent, it may not dry the tan of the bark-bed too much. In the beginning a sliding iron regulator may be fixed, either to admit or exclude the heat, as expedient; so that the smoke, by running through a larger extent, may expend its heat wholly in the flues; before it be discharged at the chimney. Great care should be taken that neither the fire-place nor flues be carried too near any of the wood-work of the buildings.

After this work is done, proceed to set out the cavity for the bark-pit, first allowing a space next the flues for an alley or walk, eighteen inches or two feet all round, and then in the middle space form the pit for the bark-bed, six or seven feet wide, the length in proportion to that of the house, and a yard or more deep; enclosing it by a surrounding wall. It may either be sunk at bottom a little in the ground raising the rest above by means of the parapet wall; or, if there is danger of wet below, it should be raised a little above the general surface. The surrounding wall should be nine inches, but a half-brick wall is often made to do, especially for that part which forms the parapet above ground. It should be coped all round with a timber plate or kirb, framed and mortised together, which effectually secures the brick-work in its proper situation.

The bottom of the pit should be levelled and well rammed, and, if paved with any coarse material, it is of advantage in preserving the bark. The path or alley round the pit should also be neatly paved with brick or stone, as may be most convenient.

The glass part for enclosing the whole, should consist of a close continued range of glass sashes all along the front, both ends and roof, quite up to the back wall; each sash being three feet or three feet six inches wide; and for the support of these, framings of timber must be erected in the brick walling, conformable to the width and length of the sashes, the whole being neatly fixed.

For the reception of the perpendicular glasses in the front and ends, a substantial timber plate must be placed along the top of the front and end walls, upon which should be erected uprights, at proper distances, framed to a plate or crown-piece above, of sufficient height to raise the whole front head-high, both ends corresponding with the front and back. To receive the sloping bars from the frame-work in front, a plate of timber must be framed to the back wall above, proper grooves being formed in the front plate below and above, to receive the ends of the perpendicular sashes, sliding close against the outside of the uprights all the way along the front. Or they may be contrived for only every other sash, to slide one on the side of the other, but the former is the better method.

From the top of the upright framing in front should be carried substantial cross-bars or bearers, sloping to the back wall, where they are framed at both ends to the wood-work or plates, at regular distances, to receive and support the sloping glass sashes of the roof. These are placed close together upon the cross-bars or rafters, and generally range in two or more tiers, sliding one over the other, of sufficient length together to reach quite from the top of the upright framing in front to the top of the back wall. The cross-bars should be grooved lengthwise above, to carry off wet falling between the frames of the sloping lights; and the upper end of the tier of glasses should shut close up to the plate in the wall behind, running under a proper coping of wood or lead which must be fixed along above close to the wall, and lapped down, of due width to cover, and shoot off the wet sufficiently from the upper termination of the top sashes. Some wide houses have, exclusive of the sliding glass sashes of the main slope, a shorter upper tier of glass fixed; the upper ends being secured under a coping as above, and the lower ends lapping over the top ends of the upper sliding tier, and this over that below in the same manner, so as to shoot the wet clear over each upper end or termination. Likewise, along the under outer edge of the top plate or crown-piece in front may be a small channel to receive the water from the sloping glass sashes, and convey it to one or both ends without running down upon the upright sashes, being careful that the

top part behind be well framed and secured water-tight, and the top of the back wall finished a little higher than the glass with a neat coping the whole length of the building.

The bars of wood which support the glasses should be neatly formed, and made neither very broad nor thick, to intercept the rays of the sun. Those, however, at top, should be made strong enough to support the glasses without bending under them. In wide houses, uprights are arranged within, at proper distances to support the cross rafters more perfectly than could otherwise be the case.

But in respect to the glass-work in the sloping sashes, the panes of glass should be laid in putty, with the ends lapping over each other about half an inch, the vacancies of which are, in some, closed up at bottom with putty; others leave each lapping of the panes open, for the admission of air, and that the rancid vapours arising from the fermentation of the bark-bed, &c., within, may thereby be kept in constant motion, to diminish condensation, and also, that such as condense against the glasses may discharge themselves at those places without dropping upon the plants. The upright sashes in front may either be glazed as above, or the panes laid in lead-work; being very careful to have the glazing well performed, and proof against any wet that may happen to beat against them. The doors should have the upper parts sashed and glazed to correspond with the other glass-work of the house.

On the inside, the walls should be plastered, pargeted, and white-washed: and all the wood-work, within and without, painted white in oil-colour. Some, however, have the back wall painted or coloured rather dark.

Ranges of narrow shelves, for pots of small plants, may be erected where most convenient, some behind over the flues, a single range near the top glasses towards the back part, supported either by brackets suspended from the cross-bars above, or by uprights erected on the parapet wall of the bark-pit. A range or two of narrow ones may also be placed occasionally along both ends above the flues, where there is a necessity for a very great number.

In wide houses, where the cross-bars or bearers of the sloping or top glass sashes appear to want support, some neat uprights, either of wood or iron, may be erected upon the bark-bed walling, at convenient distances, and high enough to reach the bearers above. This is a neat mode of affording them support.

On the outside, behind, should be erected a close shed, the whole length, or at least a small covered shed over each fire-place, with a door to shut, for the convenience of attending the fires. The former is much the best, as it will serve to defend the back of the house from the outward air, and to stow fuel; also for garden tools when not in use; as well as to lay portions of earth in occasionally, to have it dry for particular purposes in winter and early spring, as in forcing-frames, &c.

Sometimes hot-houses are furnished with top-covers, to draw over the glass sashes occasionally, in time of severe frosts and storms; and sometimes by slight sliding shutters, fitted to the width of the separate sashes; but these are inconvenient, and require considerable time and trouble in their application. At other times they are formed of painted canvass, on long poles or rollers, fixed lengthwise along the tops of the houses, just above the upper ends of the top sashes, which, by means of lines and pulleys, are readily let down and rolled up, as there may be occasion.

HOVEL (Saxon), a low building, with some part of the lower side open, to afford shelter to young animals during stormy weather.

HOVELING, the carrying up of the sides of a chimney, that when the wind rushes over the mouth, the smoke may escape below the current, or against any one side of it. The working up of the sides is covered at the top with tiles or bricks in a pyramidal form, in order to get rid of the inconvenience occasioned by adjoining buildings being higher than the chimney, or by its being in the eddy of any very lofty buildings, or in the vicinity of high trees; in which cases the covered side must be towards the building.

HOUSE, a habitation, or a building constructed for sheltering a man's person and goods from the inclemencies of the weather, and the injuries of ill-disposed persons. Houses differ in magnitude, being of two or three, and four stories; in the materials of which they consist, as wood, brick, or stone; and in the purposes for which they are designed, as a manor-house, farm-house, cottage, &c.

A pleasure-house, or country-house, is one built for occasional residence, and for the pleasure and benefit of retirement, air, &c. This is the *villa* of the ancient Romans; and what in Spain and Portugal they call *quinta;* in Provence, *cassino;* in some other parts of France, *closerie;* in Italy, *vigna.*

The citizens of Paris have also their *maisons de bouteilles* (bottle-houses) to retire to, and entertain their friends; which, in Latin, might be called *micæ;* the emperor Domitian having a house built for the like purpose, mentioned under this name by Martial.

It is a thing principally to be aimed at, in the site or situation of a country-house, or seat, that it have wood and water near it.

It is far better to have a house defended by trees than hills: for trees yield a cooling, refreshing, sweet, and healthy air and shade during the heat of the summer, and very much break the cold winds and tempests from every point in the winter. The hills, according to their situation, defend only from certain winds; and, if they are on the north side of the house, as they defend from the cold air in the winter, so they also deprive you of the cool refreshing breezes which are commonly blown from thence in the summer; and if the hills are situate on the south side, they then prove also very inconvenient.

A house should not be too low-seated, since this precludes the convenience of cellars. If you cannot avoid building on low grounds, set the first floor above the ground the higher, to supply what you want to sink in your cellar in the ground; for in such low and moist grounds, it conduces much to the dryness and healthiness of the air to have cellars under the house, so that the floors be good, and ceiled underneath. Houses built too high, in places obvious to the winds, and not well defended by hills or trees, require more materials to build them, and more also of reparations to maintain them; and they are not so commodious to the inhabitants as the lower-built houses, which may be built at a much easier rate, and also as complete and beautiful as the other.

In houses not above two stories with the ground-room, and not exceeding twenty feet to the wall-plate, and upon a good foundation, the length of two bricks, or eighteen inches for the heading course, will be sufficient for the ground-work of any common structure, and six or seven courses above the earth to a water-table, where the thickness of the walls is abated or taken in on either side the thickness of brick, namely, two inches and a quarter.

For large and high houses, or buildings of three, four, or five stories, with the garrets, the walls of such edifices ought to be from the foundation to the first water-table three heading courses of brick, or 28 inches at least; and at every story a water-table, or taking in on the inside for the girders and joists to rest upon, laid into the middle, or one quarter of the wall at least, for the better bond. But as for the innermost or partition wall, a half brick will be sufficiently thick;

and for the upper stories, nine inches or a brick length will suffice.

The general principles of the construction of edifices and private houses will be found under the article BUILDING. We shall under this head give a description of the private houses of the ancients: —

Of the private dwellings of the ancients, we have but little or no account, and it is probable that they possessed but small pretensions to architectural grandeur. We hear of temples, palaces, and such like public buildings, and of these we have careful and detailed descriptions, but of the habitations of the mass of the people, we have only a cursory notice. This fact would lead us to believe that but little attention was paid to domestic buildings of the earlier periods of history, and such indeed seems to have been the case; all the care of the people being confined to the temples of their gods, and the palaces of their governors. With a proper though misplaced zeal, the taste of their architects was exhausted in erecting and adorning the habitations of their deities; and indeed in all ages and countries, the art seems to be principally indebted for its progress to the religious feelings of mankind.

In his description of Babylon, Herodotus speaks of houses being ranged on either side of the various streets into which the city was divided, and of others of a smaller character, on either side of the outer wall, so placed as to allow of a wide passage or roadway between the two ranges. The former are described as consisting of three or four stories, and the latter of only one story.

If we may form a judgment from the paintings of the ancient Egyptians, their domestic buildings were of very uniform character. Some houses were two or three stories in height, and these seem to have belonged to the more common sort, but the larger mansions were only of one story, but of considerable extent in plan. They consisted of one or more rectangular courts surrounded by chambers similar to the existing specimens of Roman construction; or sometimes a group of building was placed in the centre of such a court. The roofs, as in all Eastern buildings, were flat, and probably covered with an awning, as a protection from the heat.

According to Pliny, the Greeks originally dwelt in caves, and were taught the art of house-building by two brothers, Euryalus and Hyperbius, who were Tyrrhenians, from which nation buildings of all kinds are said to have been introduced into Greece. During their early history, up to the time of Aristides and Pericles, their dwellings were of a very simple description, nor did they arrive at any magnificence until the time of Alexander, when they had given themselves over to a luxurious mode of living. At this period their dwellings became of great extent, and were very highly embellished, being similar in form and arrangement to those of the Romans,—of which in all probability they afforded the idea—but far inferior to them in extent and magnificence. Ere, however, the Romans had become thus extravagant in the adornment of their villas, they had passed through the same stages as their predecessors, and it was not until by their conquests they had become acquainted with the luxury of Asia and Greece, that they began to erect such splendid mansions. The villa of Marcus Cato, we are told, was so rude, that the walls were not even plastered; nor did that of Scipio Africanus, or the Villa Publica, greatly excel in richness of decoration. The first houses of the Romans were nothing better than simple cottages thatched with straw; and when the city was rebuilt after it was burned by the Gauls, the houses were mostly constructed of wood and covered with shingles, although of so great a height as to become dangerous. This was the case. even in the reign of Augustus. The greater part of the city was again destroyed by fire in the time of Nero, and was rebuilt in a more substantial and elegant manner; but we can form only a remote idea of the houses, having no examples remaining.

The country seats or villas were the dwellings on which the higher classes expended the greatest care, and a full description of these will be found in Pliny's Letters, which we proceed to give, but, before doing so, insert some remarks and directions on the subject by Vitruvius.

Of the private and public Apartments of Houses, and of their Construction according to the different Ranks of People; (from Vitruvius.)

"These buildings being disposed to the proper aspects of the heavens, then the distribution of such places in private houses as are appropriated to the use of the master of the house, and those which are common for strangers, must be also considered: for into those that are thus appropriated, no one can enter unless invited; such as the cubiculum, the triclinium, the bath, and others of similar use. The common are those which the people unasked may legally enter; such are the vestibulum, cavædium, peristylium, and those that may answer the same purposes: but to persons of the common rank, the magnificent vestibulum, tablinum, or atrium, are not necessary, because such persons pay their court to those who are courted by others.

"People who deal in the produce of the country must have stalls and shops in their vestibules, and cryptæ, horreæ, and apothecæ, in their houses, which should be constructed in such a manner as may best preserve their goods rather than be elegant. The houses of bankers, and public offices, should be more commodious and handsome, and made secure from robbers; those of advocates and the learned, elegant and spacious, for the reception of company; but those of the nobles, who bear the honours of magistracy, and decide the affairs of the citizens, should have a princely vestibulum, lofty atrium, and ample peristylium, with groves and extensive ambulatories,erected in a majesticstyle; besides libraries, pinacothecas, and basilicas, decorated in a manner similar to the magnificence of public buildings; for in these places, both public affairs and private causes are oftentimes determined. Houses therefore being thus adapted to the various degrees of people, according to the rules of decor, explained in the first book, will not be liable to censure, and will be convenient and suitable to all purposes. These rules also are applicable, not only to city houses, but likewise to those of the country; except that in those of the city the atrium is usually near the gate, whereas in the country pseudo-urbana, the peristylium is the first, and then the atrium; having a paved porticus around, looking to the palestra and ambulatories.

"I have, as well as I have been able, briefly written the rules relative to city houses, as I proposed. I shall now treat of those in the country, how they may be made convenient, and in what manner they should be disposed.

"*Of Country Houses, with the description and use of their several Parts.*

"In the first place, the country should be examined with regard to its salubrity, as written in the first book concerning the founding of a city, for in like manner villas are to be established. Their magnitude must be according to the quantity of land and its produce. The courts and their size must be determined by the number of cattle and yokes of oxen to be there employed. In the warmest part of the court, the kitchen is to be situated, and adjoining thereto the ox-house, with the stalls turned towards the fire and the eastern sky; for the cattle seeing the light and fire, are thereby rendered smooth-coated; even husbandmen, although ignorant of the

nature of aspects, think that cattle should look to no other part of the heavens than to that where the sun rises. The breadth of the ox-house should not be less than ten feet, nor more than fifteen; the length should be so much as to allow no less than seventeen feet to each yoke.

"The bath also is to be adjoined to the kitchen, for thus the place of bathing will not be far from those of the husbandry occupations. The press-room should be near the kitchen, that it may be convenient for the olive business; and adjoining thereto the wine-cellar, having windows to the north; for, should they be toward any part which may be heated by the sun, the wine in that cellar would be disturbed by the heat, and become vapid. The oil-room is to be so situated as to have its light from the southern and hot aspects; for oil ought not to be congealed, but be attenuated by a gentle heat. The dimensions of these rooms are to be regulated by the quantity of fruit, and the number of the vessels; which, if they be cullearim, should in the middle occupy four feet. Also, if the press be not worked by screws, but by levers, the press room should not be less than forty feet long, that the pressers may have sufficient space; the breadth should not be less than sixteen feet, by which means there will be free room to turn, and to dispatch the work; but if there be two presses in the place, it ought to be twenty-four feet broad. The sheep and goat-houses should be so large, that not less than four feet and a half, nor more than six feet, may be allowed to each animal. The granary should be elevated from the ground, and look to the north or east, for thus the grain will not so soon be heated, but, being cooled by the air, will endure the longer; the other aspects generate worms and such vermin as usually destroy the grain.

"The stable, above all in the villa, should be built in the warmest place, and not look toward the fire, for if these cattle be stalled near the fire, they become rough-coated; nor are those stalls unuseful which are placed out of the kitchen, in the open air, toward the east; for in the winter time, when the weather is serene, the beasts, being led thither in the morning, may be cleaned while they are taking their food.

"The barn, hay-room, meal-room, and mill, are placed without the villa, that it may be more secure from the danger of fire.

"If the villa is to be built more elegantly, it must be constructed according to the symmetry of city houses, before described: but so as not to impede its use as a villa.

"Great care ought to be taken, that all buildings have sufficient light, which in villas is easily obtained; because there are no walls near to obstruct it. But in the city, either the height of the party-walls, or the narrowness of the streets, may occasion obscurity. It may, however, be thus tried: on the side where the light is to be received, let a line be extended from the top of the wall that seems to cause the obscurity, to that place to which the light is required; and if, when looking up along that line, an ample space of the clear sky may be seen, the light to that place will not be obstructed; but if beams, lintels, or floors, interfere, the upper parts must be opened, and thus the light be admitted. The upper rooms are thus to be managed; on whatsoever part of the heavens the prospect may lie, on that side the places of the windows are to be left, for thus the edifice will be best enlightened. As in tricliniums and such apartments, the light is highly necessary, so also is it in passages, ascents, and staircases, where people carrying burdens frequently meet each other.

"I have explained, as well as I have been able, the distribution of our buildings, that they may not be unknown to those who build; I shall now also briefly explain the distribution of houses, according to the custom of the Greeks, that they also may not be unknown.

"*Of the Disposition of the Houses of the Greeks.*

"The Greeks use no atrium, nor do they build in our manner; but from the gate of entrance they make a passage of no great breadth; on one side of which is the stable, on the other, the porters' rooms, and these are directly terminated by the inner gates. This place between the two gates is called by the Greeks *thyroreion.* After that, in entering, is the peristylium, which peristylium has porticos on three sides. On that side which looks to the south, are two antæ, at an ample distance from each other, supporting beams, and so much as is equal to the distance between the antæ, wanting a third part, is given to the space inwardly; this place is called by some *prostas*, by others *parastas.* From this place, more inwardly, the great œci are situated, in which the mistress of the family, with the workwomen, resides. On the right and left of the prostas, are cubiculæ, of which one is called *thalamas*, and the other *amphithalamas;* and in the surrounding porticos, the common tricliniums, cubiculums, and family rooms are erected. This part of the edifice is called *gynæconitis.*

"Adjoining to this is a larger house, having a more ample peristylium, in which are four porticos of equal height, or sometimes the one which looks towards the south has higher columns; and this peristylium, which has one portico higher than the rest, is termed *rhodian.* In these houses they have elegant vestibulums, magnificent gates, and the porticos of the peristyliums are ornamented with stucco, plaster, and lucunariæ, of inside work (wood.) In the porticos which look to the north, are the Cyzicene triclinium, and pinacothecæ: to the east are the libraries, to the west the exedræ, and in those looking to the south are the square œci, so large that they may easily contain four sets of dining couches, with the attendants, and a spacious place for the use of the games. In these œci are made the men's dining couches, for it is not their custom for the mothers of families to lie down to dine. This peristylium and part of the house is called *andronitides*, because here the men only are invited without being accompanied by the women.

"On the right and left also, small houses are erected, having proper gates, triclinæ, and convenient cubiculæ, that when strangers arrive, they may not enter the peristylium, but be received in this hospitalium; for when the Greeks were more refined and opulent, they prepared tricliniæ, cubiculæ, and provisions, for strangers; the first day inviting them to dinner, afterwards sending them poultry, eggs, herbs, fruits, and other productions of the country. Hence the pictures representing the sending of gifts to strangers, are by the painters called *zenia.* Masters of families, therefore, while they abode in the hospitium, seemed not to be from home, having the full retirement in these hospitaliums. Between the peristylium and hospitalium are passages, which are called *mesaulæ;* because they are situated between two *aulæ*; these are by us called *andronas;* but it is remarkable that the Greeks and Latins do not in this agree; for the Greeks give the name of *andronas* to the œcus where the men usually dine, and which the women do not enter.

"It is the same also with some other words, as *xystos*, *prothyrum*, *telamones*, and others; for *xystos* is the Greek appellation of those broad porticos, in which the athletæ exercise in winter time; whereas, we call the uncovered ambulatories *xystos;* and which the Greeks call *peridromidas.* The *vestibula*, which are before the gates, are by the Greeks called *prothyra;* whereas, we call *prothyra* that which the Greeks call *diathyra.* The statues of men bearing mutules or cornices we call *telamones*, for what reason is nc tc be

found in history; but the Greeks call them *atlantes;* Atlas being in history represented as supporting the world; for he was the first who, by his ingenuity and diligence, discovered and taught mankind the course of the sun and moon, the rising and setting of all the planets, and the revolutions of the heavens; for which benefit the painters and statuaries represented him bearing the whole earth; and the Atlantides, his children, which we call *Vergilius*, and the Greeks *Pheïades*, are placed among the stars in the heavens. I have not, however, mentioned this in order to change the customary names or manner of discoursing, but only to explain them, that these things might not be unknown to the lovers of knowledge."

Extracts from Pliny's Letters.

Description of the villa at Laurentinum.

"You are surprised, it seems, that I am so fond of my Laurentinum, or (if you like the appellation better) my Laurens; but you will cease to wonder, when I acquaint you with the beauty of the villa, the advantages of its situation, and the extensive prospect of the sea-coast. It is but seventeen miles distant from Rome; so that, having finished my affairs in town, I can pass my evenings here, without breaking in upon the business of the day. There are two different roads to it: if you go by that of Laurentum, you must turn off at the fourteenth mile-stone; if by Ostia, at the eleventh. Both of them are, in some parts, sandy, which makes it somewhat heavy and tedious, if you travel in a carriage, but easy and pleasant to those who ride on horseback. The landscape, on all sides, is extremely diversified, the prospect, in some places, being confined by woods, in others extending over large and beautiful meadows, where numberless flocks of sheep and herds of cattle, which the severity of the winter has driven from the mountains, fatten in the vernal warmth of this rich pasturage. My villa is large enough to afford all desirable accommodations, without being extensive. The porch before it is plain, but not mean, through which you enter into a portico in the form of the letter D, which includes a small but agreeable area. This affords a very commodious retreat in bad weather, not only as it is enclosed with windows, but particularly as it is sheltered by an extraordinary projection of the roof. From the middle of this portico you pass into an inward court, extremely pleasant, and from thence into a handsome hall, which runs out towards the sea; so that when there is a south-west wind, it is gently washed with the waves, which spend themselves at the foot of it. On every side of this hall, there are either folding-doors, or windows equally large, by which means you have a view from the front and the two sides, as it were, of three different seas: from the back part, you see the middle court, the portico, and the area; and, by another view, you look through the portico, into the porch, from whence the prospect is terminated by the woods and mountains which are seen at a distance. On the left-hand of this hall, somewhat farther from the sea, lies a large drawing-room, and beyond that, a second of a smaller size, which has one window to the rising, and another to the setting sun: this has, likewise, a prospect of the sea, but being at a greater distance, is less incommoded by it. The angle which the projection of the hall forms with this drawing-room, retains and increases the warmth of the sun; and hither my family retreat in winter to perform their exercises: it is sheltered from all winds, except those which are generally attended with clouds, so that nothing can render this place useless, but what, at the same time, destroys the fair weather. Contiguous to this, is a room forming the segment of a circle, the windows of which are so placed, as to receive the sun the whole day: in the walls are contrived a sort of cases, which contain a collection of such authors whose works can never be read too often. From hence you pass into a bed-chamber through a passage, which, being boarded, and suspended, as it were, over a stove which runs underneath, tempers the heat which it receives, and conveys it to all parts of this room. The remainder of this side of the house is appropriated to the use of my slaves and freed-men: but most of the apartments, however, are neat enough to receive any of my friends. In the opposite wing, is a room ornamented in a very elegant taste; next to which lies another room, which, though large for a parlour, makes but a moderate dining-room; it is exceedingly warmed and enlightened, not only by the direct rays of the sun, but by their reflection from the sea. Beyond, is a bed-chamber, together with its ante-chamber, the height of which renders it cool in summer; as its being sheltered on all sides from the winds makes it warm in winter. To this apartment another of the same sort is joined by one common wall. From thence you enter into the grand and spacious cooling-room, belonging to the bath, from the opposite walls of which, two round basons project, sufficiently large to swim in. Contiguous to this is the perfuming-room, then the sweating-room, and next to that, the furnace which conveys the heat to the baths: adjoining, are two other little bathing-rooms, fitted up in an elegant rather than costly manner: annexed to this, is a warm bath of extraordinary workmanship, wherein one may swim, and have a prospect, at the same time, of the sea. Not far from hence, stands the tennis court, which lies open to the warmth of the afternoon sun. From thence you ascend a sort of turret, containing two entire apartments below; as there are the same number above, besides a dining-room which commands a very extensive prospect of the sea, together with the beautiful villas that stand interspersed upon the coast. At the other end, is a second turret, in which is a room that receives the rising and setting sun. Behind this is a large repository, near to which is a gallery of curiosities, and underneath a spacious dining-room, where the roaring of the sea, even in a storm, is heard but faintly: it looks upon the garden, and the *gestatio* which surrounds the garden. The gestatio is encompassed with a box-tree hedge, and where that is decayed, with rosemary; for the box, in those parts which are sheltered by the buildings, preserves its verdure perfectly well; but where, by an open situation, it lies exposed to the spray of the sea, though at a great distance, it entirely withers. Between the garden and this gestatio runs a shady plantation of vines, the alley of which is so soft, that you may walk bare-foot upon it without any injury. The garden is chiefly planted with fig and mulberry trees, to which this soil is as favourable, as it is averse from all others. In this place is a banqueting-room, which, though it stands remote from the sea, enjoys a prospect nothing inferior to that view: two apartments run round the back part of it, the windows whereof look upon the entrance of the villa, and into a very pleasant kitchen-ground. From hence an enclosed portico extends, which, by its great length, you might suppose erected for the use of the public. It has a range of windows on each side, but on that which looks towards the sea, they are double the number of those next the garden. When the weather is fair and serene, these are all thrown open; but if it blows, those on the side the wind sets are shut, while the others remain unclosed without any inconvenience. Before this portico lies a terrace, perfumed with violets, and warmed by the reflection of the sun from the portico, which, as it retains the rays, so it keeps off the north-east wind: and it is as warm on this side as it is cool on the opposite: in the same manner it proves a defence against the south-west; and thus, in short,

by means of its several sides, breaks the force of the winds from what point soever they blow. These are some of its winter advantages: they are still more considerable in summer; for at that season it throws a shade upon the terrace during all the forenoon, as it defends the gestatio, and that part of the garden which lies contiguous to it, from the afternoon sun, and casts a greater or less shade, as the day either increases or decreases; but the portico itself is then coolest, when the sun is most scorching, that is, when its rays fall directly upon the roof. To these its benefits I must not forgot to add, that, by setting open the windows, the western breezes have a free draught, and, by that means, the enclosed air is prevented from stagnating. On the upper end of the terrace and portico stands a detached building in the garden, which I call my favourite; and indeed it is particularly so, having erected it myself. It contains a very warm winter-room, one side of which looks upon the terrace, the other has a view of the sea, and both lie exposed to the sun. Through the folding-doors you see the opposite chamber, and from the window is a prospect of the enclosed portico. On that side next the sea, and opposite to the middle wall, stands a little elegant recess, which, by means of glass-doors and a curtain, is either laid into the adjoining room, or separated from it. It contains a couch and two chairs. As you lie upon this couch, from the feet you have a prospect of the sea; if you look behind, you see the neighbouring villas; and from the head you have a view of the woods; these three views may be seen either distinctly from so many different windows in the room, or blended together in one confused prospect. Adjoining to this is a bed-chamber, which neither the voice of the servants, the murmuring of the sea, nor even the roaring of a tempest, can reach; not lightning nor the day itself can penetrate it, unless you open the windows. This profound tranquillity is occasioned by a passage, which separates the wall of this chamber from that of the garden; and thus, by means of that intervening space, every noise is precluded. Annexed to this is a small stove-room, which, by opening a little window, warms the bed-chamber to the degree of heat required. Beyond this lies a chamber and anti-chamber, which enjoys the sun, though obliquely indeed, from the time it rises, till the afternoon. When I retire to this garden-apartment, I fancy myself a hundred miles from my own house, and take particular pleasure in it at the feast of the Saturnalia, when, by the license of that season of festivity, every other part of my villa resounds with the mirth of my domestics: thus I neither interrupt their diversions, nor they my studies. Among the pleasures and conveniences of this situation, there is one disadvantage, and that is the want of a running stream; but this defect is, in a great measure, supplied by wells, or rather I should call them fountains, for they rise very near the surface. And, indeed, the quality of this coast is remarkable; for in what part soever you dig, you meet, upon the first turning up of the ground, with a spring of pure water, not in the least salt, though so near the sea. The neighbouring forests afford an abundant supply of fuel; as every other accommodation of life may be had from Ostia: to a moderate man, indeed, even the next village (between which and my house there is only one villa) would furnish all common necessaries. In that little place there are no less than three public baths; which is a great conveniency, if it happen that my friends come in unexpectedly, or make too short a stay to allow time for preparing my own. The whole coast is beautifully diversified by the contiguous or detached villas that are spread upon it, which, whether you view them from the sea or the shore, have the appearance of so many different cities. The strand is sometimes, after a long calm, perfectly smooth, though, in general, by the storms driving the waves upon it, it is rough and uneven. I cannot boast that our sea produces any very extraordinary fish; however, it supplies us with exceeding fine soles and prawns; but as to provisions of other kinds, my villa pretends to excel even inland countries, particularly in milk; for hither the cattle come from the meadows in great numbers, in pursuit of shade and water.

"Tell me now, have I not just cause to bestow my time and my affection upon this delightful retreat? Surely you are too fondly attached to the pleasures of the town, if you do not feel an inclination to take a view of this my favourite villa. I much wish, at least, you were so disposed, that to the many charms with which it abounds, it might have the very considerable addition of your company to recommend it. Farewell."

The following observations may tend to illustrate several of the obscure parts, in the foregoing description of Pliny's villa at Laurentinum.

Pliny had no estate round his seat at Laurentinum; his whole possessions there being included (as he informs us, B. 4. let. 3.) in the house and garden. It was merely a winter villa, in which he used to spend some of the cold months, whenever his business admitted of his absence from Rome; and, for this reason it is, that we find warmth is so much considered in the disposition of the several apartments, &c. And, indeed, he seems to have a principal view to its advantages as a winter house, throughout the whole description of it.

Scamozzi, in his *Architect. Univers.* lib. 3. 12. has given a plan and elevation of this villa. Mons. Felibien has also annexed a plan to his translation of this letter; as our own countryman, the ingenious Mr. Castel, has done in his *Villas of the Ancients illustrated.* But they differ extremely among themselves as to the disposition of the several parts of this building, and, perhaps, have rather pursued the idea of modern architecture, than that which is traced out in their original; at least, if the supposition advanced by one of the commentators upon this epistle be true; who contends that the villas of the ancients were not one uniform pile of building contained under the same roof, but that each apartment formed a distinct and separate member from the rest. The ruins of this villa are said to have been discovered some time about the year 1714, but whether any plan was ever taken of so valuable a remain of antiquity, or the reality of it ascertained, the translator has not been able to learn.

The Roman magnificence seems to have particularly displayed itself in the article of their baths. Seneca, dating one of his epistles from a villa which once belonged to Scipio Africanus, takes occasion, from thence, to draw a parallel between the simplicity of the earlier ages, and the luxury of his own times in that instance. By the idea he gives of the latter, they were works of the highest splendour and expense. The walls were composed of Alexandrine marble, the veins whereof were so artfully managed, as to have the appearance of a regular picture: the edges of the basons were set round with a most valuable kind of stone, found in Thasius, one of the Greek islands, variegated with veins of different colours, interspersed with streaks of gold; the water was conveyed through silver pipes, and fell, by several descents, in beautiful cascades. The floors were inlaid with precious gems, and an intermixture of statues and colonnades contributed to throw an air of elegance and grandeur upon the whole. *Vide* Sen. *Ep.* 86.

"The custom of bathing in hot water was become so habitual to the Romans, in Pliny's time, that they every day practised it before they lay down to eat, for which reason,

in the city, the public baths were extremely numerous; in which Vitruvius gives us to understand, there were, for each sex, three rooms for bathing, one of cold water, one of warm, and one still warmer; and there were cells of three degrees of heat, for sweating: to the fore-mentioned members, were added others for anointing and bodily exercises. The last thing they did before they entered into the dining-room was to bathe; what preceded their washing was their exercise in the spheristerium, prior to which it was their custom to anoint themselves. As for their sweating-rooms, though they were, doubtless, in all their baths, we do not find them used but upon particular occasions." Castel's *Villas of the Ancients*, p. 31.

"The enclosed porticos in Pliny's description differed no otherwise from our present galleries, than that they had pillars in them: the use of this room was for walking." Castel's *Villas*, p. 44.

Mr. Castel observes, that though Pliny calls his house *Villula;* it appears that, after having described but part of it, yet, if every diæta or entire apartment may be supposed to contain three rooms, he has taken notice of no less than forty-six, besides all which, there remains near half the house undescribed, which was, as he says, allotted to the use of the servants; and it is very probable this part was made uniform with that he has already described. But it must be remembered, that diminutives in Latin do not always imply smallness of size, but are frequently used as words of endearment and approbation; and in this sense it seems most probable that Pliny here uses the word *Villula.*

The following is Pliny's description of his summer villa in Tuscany, book v. letter vi., addressed to Apollinaris.

"The kind concern you expressed when you heard of my design to pass the summer at my villa in Tuscany, and your obliging endeavours to dissuade me from going to a place which you think unhealthy, are extremely pleasing to me. I confess, the atmosphere of that part of Tuscany, which lies towards the coast, is thick and unwholesome: but my house is situated at a great distance from the sea, under one of the Apennine mountains, which, of all others, is most esteemed for the clearness of its air. But that you may be relieved from all apprehensions on my account, I will give you a description of the temperature of the climate, the situation of the country, and the beauty of my villa, which I am persuaded you will read with as much pleasure as I shall relate. The winters are severe and cold, so that myrtles, olives, and trees of that kind, which delight in constant warmth, will not flourish here: but it produces bay-trees in great perfection; yet, sometimes, though indeed not oftener than in the neighbourhood of Rome, they are killed by the severity of the seasons. The summers are exceedingly temperate, and continually attended with refreshing breezes, which are seldom interrupted by high winds. If you were to come here, and see the numbers of old men who have lived to be grandfathers and great-grandfathers, and hear the stories they can entertain you with of their ancestors, you would fancy yourself born in some former age. The disposition of the country is the most beautiful that can be imagined; figure to yourself an immense amphitheatre; but such as the hand of nature only could form. Before you lies a vast extended plain, bounded by a range of mountains, whose summits are covered with lofty and venerable woods, which supply variety of game: from thence, as the mountains decline, they are adorned with underwoods. Intermixed with these are little hills of so strong and fat a soil, that it would be difficult to find a single stone upon them; their fertility is nothing inferior to the lowest grounds; and though their harvest, indeed, is somewhat later, their crops are as well matured. At the foot of these hills the eye is presented, wherever it turns, with one unbroken view of numberless vineyards, terminated by a border, as it were, of shrubs. From thence you have a prospect of the adjoining fields and meadows below. The soil of the former is so extremely stiff, and, upon the first ploughing, turns up in such vast clods, that it is necessary to go over it nine several times, with the largest oxen and the strongest ploughs, before they can be thoroughly broken; whilst the enamelled meadows produce trefoil, and other kinds of herbage, as fine and tender as if it were but just sprung up, being continually refreshed by never failing rills. But though the country abounds with great plenty of water, there are no marshes; for, as it lies upon a rising ground, whatever water it receives without absorbing, runs off into the Tiber. This river, which winds through the middle of the meadows, is navigable only in the winter and spring, at which seasons it transports the produce of the lands to Rome; but its channel is so extremely low in summer, that it scarcely deserves the name of a river; towards the autumn, however, it begins again to renew its claim to that title.—You could not be more agreeably entertained, than by taking a view of the face of this country from the top of one of our neighbouring mountains: you would suppose that not a real, but some imaginary landscape, painted by the most exquisite pencil, lay before you: such an harmonious variety of beautiful objects meets the eye, which way soever it turns. My villa is so advantageously situated, that it commands a full view of all the country round; yet you approach it by so insensible a rise, that you find yourself upon an eminence, without perceiving you ascended. Behind, but at a great distance, stands the Apennine mountains. In the calmest day we are refreshed by the winds that blow from thence, but so spent, as it were, by the long tract of land they travel over, that they are entirely divested of all their strength and violence before they reach us. The exposition of the principal front of the house is full south, and seems to invite the afternoon sun in summer (but somewhat earlier in winter) into a spacious and well-proportioned portico, consisting of several members, particularly a porch built in the ancient manner. In the front of the portico is a sort of terrace, embellished with various figures, and bounded with a box-hedge, from whence you descend by an easy slope, adorned with the representation of divers animals, in box, answering alternately to each other, into a lawn overspread with the soft, I had almost said the liquid, acanthus: this is surrounded by a walk enclosed with tonsile evergreens, shaped into a variety of forms. Beyond it is the gestatio, laid out in the form of a circus, ornamented in the middle with box cut in numberless different figures, together with a plantation of shrubs, prevented by the shears from shooting up too high: the whole is fenced in with a wall covered by box, rising by different ranges to the top. On the outside of the wall lies a meadow that owes as many beauties to nature, as all I have been describing *within* does to art; at the end of which are several other meadows and fields interspersed with thickets. At the extremity of this portico stands a grand dining-room, which opens upon one end of the terrace; as from the windows there is a very extensive prospect over the meadows up into the country, from whence you also have a view of the terrace, and such parts of the house which project forward, together with the woods enclosing the adjacent hippodrome. Opposite almost to the centre of the portico, stands a square edifice, which encompasses a small area, shaded by four plane-trees, in the midst of which a fountain rises, from whence the water, running over the edges of a marble bason, gently refreshes the surrounding plane-trees, and the verdure underneath them. This apartment consists of a bed-chamber, secured

from every kind of noise, and which the light itself cannot penetrate; together with a common dining-room, which I use when I have none but intimate friends with me. A second portico looks upon this little area, and has the same prospect with the former I just now described. There is, besides, another room, which, being situated close to the nearest plane-tree, enjoys a constant shade and verdure: its sides are incrusted half-way with carved marble; and from thence to the ceiling a foliage is painted with birds intermixed among the branches, which has an effect altogether as agreeable as that of the carving: at the basis a little fountain, playing through several small pipes into a vase, produces a most pleasing murmur. From a corner of this portico you enter into a very spacious chamber, opposite to the grand dining-room, which, from some of its windows, has a view of the terrace, and from others, of the meadow; as those in the front look upon a cascade, which entertains at once both the eye and the ear; for the water, dashing from a great height, foams over the marble bason that receives it below. This room is extremely warm in winter, being much exposed to the sun; and in a cloudy day, the heat of an adjoining stove very well supplies his absence. From hence you pass through a spacious and pleasant undressing-room into the cold-bath-room, in which is a large gloomy bath: but if you are disposed to swim more at large, or in warmer water, in the middle of the area is a wide bason for that purpose, and near it a reservoir from whence you may be supplied with cold water to brace yourself again, if you should perceive you are too much relaxed by the warm. Contiguous to the cold-bath is another of a moderate degree of heat, which enjoys the kindly warmth of the sun, but not so intensely as that of the hot-bath, which projects farther. This last consists of three divisions, each of different degrees of heat: the two former lie entirely open to the sun; the latter, though not so much exposed to its rays, receives an equal share of its light. Over the undressing-room is built the tennis-court, which, by means of particular circles, admits of different kinds of games. Not far from the baths, is the staircase leading to the enclosed portico, after you have first passed through three apartments: one of these looks upon the little area with the four plane-trees round it; the other has a sight of the meadows; and from the third you have a view of several vineyards: so that they have as many different prospects as expositions. At one end of the enclosed portico, and, indeed, taken off from it, is a chamber that looks upon the hippodrome, the vineyards, and the mountains; adjoining is a room which has a full exposure to the sun, especially in winter; and from whence runs an apartment that connects the hippodrome with the house: such is the form and aspect of the front. On the side, rises an enclosed summer portico, which has not only a prospect of the vineyards, but seems almost contiguous to them. From the middle of this portico you enter a dining-room, cooled by the salutary breezes from the Apennine valleys; from the windows in the back front, which are extremely large, there is a prospect of the vineyards; as you have also another view of them from the folding-doors, through the summer portico. Along that side of this dining-room, where there are no windows, runs a private staircase for the greater conveniency of serving at entertainments: at the farther end is a chamber from whence the eye is pleased with a view of the vineyards, and (what is not less agreeable) of the portico. Underneath this room is an enclosed portico, somewhat resembling a grotto, which, enjoying, in the midst of the summer heats, its own natural coolness, neither admits nor wants the refreshment of external breezes. After you have passed both these porticos, at the end of the dining-room stands a third, which, as the day is more or less advanced, serves either for winter or summer use. It leads to two different apartments, one containing four chambers, the other three; each enjoying, by turns, both sun and shade. In the front of these agreeable buildings, lies a very spacious hippodrome, entirely open in the middle, by which means the eye, upon your first entrance, takes in its whole extent at one glance. It is encompassed on every side with plane-trees, covered with ivy, so that while their heads flourish with their own foliage, their bodies enjoy a borrowed verdure; and thus, the ivy twining round the trunk and branches, spreads from tree to tree, and connects them together. Between each plane-tree are planted box-trees, and behind these, bay-trees, which blend their shade with that of the planes. This plantation, forming a straight boundary on both sides of the hippodrome, bends at the farther end into a semi-circle, which being set round and sheltered with cypress-trees, varies the prospect, and casts a deeper gloom; while the inward circular walks, (for there are several) enjoying an open exposure, are perfumed with roses, and connect, by a very pleasing contrast, the coolness of the shade with the warmth of the sun. Having passed through these several winding alleys, you enter a straight walk, which breaks out into a variety of others, divided by box edges. In one place you have a little meadow; in another, the box is cut into a thousand different forms; sometimes into letters, expressing the name of the master; sometimes that of the artificer; whilst here and there little obelisks rise intermixed alternately with fruit-trees: when, on a sudden, in the midst of this elegant regularity, you are surprised with an imitation of the negligent beauties of rural nature: in the centre of which lies a spot surrounded with a knot of dwarf plane-trees. Beyond these is a walk planted with the smooth and twining acanthus, where the trees are also cut into a variety of names and shapes. At the upper end is an alcove of white marble, shaded with vines, supported by four small Carystian pillars. From this bench, the water, gushing through several little pipes, as if it were pressed out by the weight of the persons who repose themselves upon it, falls into a stone cistern underneath, from whence it is received into a finely polished marble bason, so artfully contrived, that it is always full without ever overflowing. When I sup here, this bason serves for a table, the larger sort of dishes being placed round the margin, while the smaller ones swim about in the form of little vessels and water-fowl. Corresponding to this, is a fountain which is incessantly emptying and filling; for the water which it throws up a great height, falling back into it, is, by means of two openings, returned as fast as it is received. Fronting the alcove (and which reflects as great an ornament to it as it borrows from it) stands a summer-house of exquisite marble, the doors whereof project and open into a green enclosure; as from its upper and lower windows, the eye is presented with a variety of different verdures. Next to this is a little private recess (which, though it seems distinct, may be laid into the same room) furnished with a couch; and, notwithstanding it has windows on every side, yet it enjoys a very agreeable gloominess, by means of a spreading vine which climbs to the top, and entirely overshades it. Here you may recline and fancy yourself in a wood; with this difference only, that you are not exposed to the weather. In this place a fountain also rises, and instantly disappears: in different quarters are disposed several marble seats, which serve, no less than the summer-house, as so many reliefs after one is wearied with walking. Near each seat is a little fountain; and, throughout the whole hippodrome, several small rills run murmuring along, wheresoever the hand of art thought proper to conduct them, watering here and there different spots of verdure, and, in their progress, refreshing the whole.

"And now, I should not have hazarded the imputation of being too minute in this detail, if I had not proposed to lead you into every corner of my house and gardens. You will hardly, I imagine, think it a trouble to read the description of a place which, I am persuaded, would please you were you to see it; especially as you have it in your power to stop, and, by throwing aside my letter, sit down, as it were, and rest yourself as often as you think proper. I had, at the same time, a view to my own gratification; as, I confess, I have a very great affection for this villa, which was chiefly built or finished by myself. In a word (for why should I conceal from my friend my sentiments, whether right or wrong?) I look upon it as the first duty of every writer frequently to throw his eyes upon his title-page, and to consider well the subject he has proposed to himself; and he may be assured, if he precisely pursues his plan, he cannot justly be thought tedious; whereas, on the contrary, if he suffers himself to wander from it, he will most certainly incur that censure. Homer, you know, has employed many verses in the description of the arms of Achilles, as Virgil also has in those of Æneas; yet neither of them are prolix, because they each keep within the limits of their original design. Aratus, you see, is not deemed too circumstantial, though he traces and enumerates the minutest stars; for he does not go out of his way for that purpose, he only follows where his subject leads him. In the same manner (to compare small things with great) if endeavouring to give you an idea of my house, I have not deviated into any article foreign to the purpose, it is not my letter which describes, but my villa which is described, that is to be considered as large. But not to dwell any longer upon this digression, lest I should myself be condemned by the maxim I have just laid down; I have now informed you why I prefer my Tuscan villa to those which I possess at Tusculum, Tiber, and Præneste. Besides the advantages already mentioned, I here enjoy a more profound retirement, as I am at a further distance from the business of the town, and the interruption of troublesome avocations. All is calm and composed; circumstances which contribute, no less than its clear air and unclouded sky, to that health of body and cheerfulness of mind which I particularly enjoy in this place; both which I preserve by the exercise of study and hunting. Indeed, there is no place which agrees better with all my family in general; I am sure, at least, I have not yet lost one (and I speak it with the sentiments I ought) of all those I brought with me hither: may the gods continue that happiness to me, and that honour to my villa! Farewell!"

This villa in Tuscany was Pliny's principal seat, lying about 150 miles from Rome, and in which he usually resided during the summer season. The reader will observe, therefore, that he considers it in a very different manner from that of Laurentinum (his winter villa,) both with respect to the situation and the house itself. Cluver, in his geography, has placed this villa a little above *Tifernum Tiberium*, now called *Citta di Castello*, where our author built a temple at his own expense. This has given room to imagine that possibly there may be yet some remaining traces of this house to be discovered in Tuscany, near a town which the Italians call *Slintignano*, in the neighbourhood of *Ponte di San Stefano*, about ten miles north of an episcopal city now called *Borgo di San Sepulchro*.

Amongst the Jews, Greeks, and Romans, houses were flat at top, so that persons might walk upon them; and usually had stairs on the outside, by which they might ascend and descend without coming into the house. Each house, in fact, was so laid out that it enclosed a quadrangular area or court. This court was exposed to the weather, and being open to the sky, gave light to the house. This was the place where company was received, and for that purpose it was strewed with mats or carpets for their better accommodation. It was paved with marble or other materials, according to the owner's ability, and provided with an umbrella of vellum, to shelter them from the heat and inclemencies of the weather. This part of their houses, called by the Romans *impluvium* or *cava ædium*, was provided with channels to carry off the water into the common sewers. The top of the house was level, and covered with a strong plaster, by way of terrace. Hither, especially amongst the Jews, it was customary to retire for meditation, private converse, devotion, or the enjoyment of the evening breezes.

Some examples of the domestic buildings of the Romans still exist at Herculaneum and Pompeii, but they by no means equal those above described. At the former place the houses are small, and only one story in height; but at the latter we have a few on a somewhat grander scale. There are about 80 houses standing in this town, of which those of Diomedes, Sallust, and Pansa, are the finest; the second standing upon a plot of ground about 40 yards square; and the latter occupying, with its court and garden, a space of about 100 yards by 40.

Towards the close of the last, and commencement of the present century, some few examples have also been discovered in our own country. The most important is that at Woodchester, in Gloucestershire, which was discovered by Mr. Lysons in 1795, and consists of a large open court or atrium, an inner court, and a smaller one in the wing—the whole being surrounded with offices and apartments about sixty in number. The length of the apartments is about 25 feet. Another example in the same county was discovered in 1818, at Great Witcombe. Another example is that at Bignor, Sussex, discovered by Mr. Lysons in 1811, of which we give the following description, extracted from the original account, and partially from Stuart's Dictionary :—

"The first discovery of this villa occurred in 1811. A farmer who occupied the land, in removing the earth, discovered a fine mosaic pavement, which was afterwards found to have formed a part of the floor to one of the rooms. In the centre of this apartment was an hexagonal *piscina*, or cistern, formed of a hard white sort of stone, 4 feet in diameter and 1 foot 7¾ inches in depth, with a border of stone round it 9¼ inches wide, and a step within it, at nearly half its depth, 5½ inches wide; at the bottom is a round hole, 3 inches in diameter, from which a leaden pipe for carrying off the water was afterwards discovered on the outside of the south wall, running in a southern direction. The room appeared to have been heated by an hypocaust, and, in clearing away the earth, part of a small Doric column was found. In the next room discovered, the walls remained to the height of more than two feet at the north-east corner, where was a funnel above the pavement, communicating with the hypocaust below. The pavement was in good preservation; and the dimensions of the room were 40 feet 4 inches by 17 feet. The first room, 31 feet 11 inches by 19 feet. The walls on the east, west, and north sides, were 2 feet 6 inches thick; that on the south, 3 feet. This is conjectured to have been the *triclinium*, or grand banqueting room. Another pavement was found in a third room, at the end of which, opposite from the room last mentioned, was a doorway 3 feet 3½ inches wide, leading into another room, 22 feet by 10 feet 4 inches—the pavement formed of coarse red tesseræ. On the south side of the great pavement, the foundations of a cryptoporticus were discovered, which appears to have been of much larger dimensions than any one hitherto discovered in this island; it was 10 feet wide, and 157 feet 6 inches long. Its

tessellated pavement was destroyed, except at the west end; on the north side of this gallery the foundation-walls of a range of rooms was discovered, running eastward, in a line with the great room first discovered. The one which adjoined that room on the east side was 19 feet 2 inches by 18 feet 9 inches, and had a floor of terras of a light red colour. The next room to the eastward was nearly of the same dimensions, and had a coarse tessellated pavement. Adjoining the two last-mentioned rooms on the north side, were the foundations of one 16 feet square, containing a mosaic pavement. The *præfurnium* of the hypocaust, by which the great room and others had been heated, was discovered on the north side of the north wall of the third-mentioned room, and consisted of two walls 18 inches thick and 18 inches asunder, projecting 16 inches from the wall of the building; between them was a kind of arch formed by bricks projecting beyond each other, and communicating with the flues under the different pavements; about 30 feet north of the room, marked 5, in Mr. Lysons' plan, a very fine mosaic pavement was discovered, and a magnificent apartment, marked 3, was traced, to which 5 was found to have served as an ante-room. The wall on the north side of this room was found to continue 32 feet towards the west, where it terminated with a projection or buttress of two feet, forming two sides of what appeared to have been a kind of court, enclosing an area of 30 feet, filled with great quantities of stones, bricks, and tiles. At a small distance from the west wall of the great room, last described, the base and part of the shaft of a small column were discovered. At the west end of the ante-room, 5, was a very small room, 4, (9 feet by 12 feet,) having two doorways, one on the east, opening into 5, and the other on the north, communicating with the square area marked 1. The continuation of the east wall of the room 11, at the west end, or rather the continuation of the cryptoporticus, was next explored to the southward, and traces of it were found to the extent of 100 feet. The room 27, adjoining 26, had its walls still remaining on the east, north, and south sides, to about two feet high, which were covered with stucco two inches thick, painted red, with a skirting of plaster at two inches high, projecting two inches and a half from the wall. On the east side was found, in good preservation, a fireplace $21\frac{1}{2}$ inches wide in front, 17 at the back, and 8 deep, with a hearth formed of 8 bricks, each about 7 inches square. The fireplace was formed by two brick tiles on each side, which had been cramped together with iron, and were placed on the sides of the stove introduced by Count Rumford. I am not aware, Mr. Lysons observes, of any open fireplace of this kind having been discovered elsewhere in the remains of a Roman building, though it is certain, from various passages in the Roman writers, that other means were employed by the ancients for warming their apartments, besides hypocausts. The *caminus* is mentioned by Cicero, Horace, Vitruvius, and others; but the learned commentators on these authors are by no means agreed as to its form or situation, and it has been much questioned by some of them, on the authority of several passages in ancient writers, and from none having been discovered in Roman buildings, whether there was any chimney, or other means of conveying away the smoke, though it is hardly to be conceived that a room could have been habitable under such circumstances at times, when it was necessary to close the doors and windows.

This room was $14\frac{1}{2}$ by 17; the room 29 was 16 feet 5 inches by 15 feet 6 inches, and against the wall was another fireplace resembling the one described. The range of rooms running eastward from the great triclinium, were found to extend the whole length of the cryptoporticus 10.11. On the south side of the building, another cryptoporticus was discovered, marked 45; which communicated with a range of 12 rooms, containing nothing remarkable except those at the east end, which furnished many interesting remains of baths. The room 56 is nearly a square of 25 feet, and con tained a finely preserved mosaic pavement. Beyond this mosaic pavement were three rows of black and red tiles, 6 inches square, laid chequer-wise; and next to the wall a row of bricks, each 11 inches by $15\frac{1}{2}$. Great part of a small stone column was found on the pavement, in the same style as the fragment first discovered, being a sort of irregular Doric, the tori of the base being both of the same size. The adjoining room 55 was 30 feet by 25; the floor formed of black and white stones, and next to the wall a row of bricks. Nearly in the middle, was a cold bath 18 feet from east to west, and 3 feet 2 inches deep; it had 3 steps on the east, north, and west sides. On the west side of this room appeared the remains of an extensive hypocaust marked 53 54; and from the frequency of the brick piers, it appeared that the apartment over it must have been a sudatory, probably divided into several smaller rooms. The præfurnium was on the outside of the wall, on the south end; the piers were 2 feet 9 inches high, and $7\frac{1}{2}$ inches square, and consisted of 18 layers of bricks, with a larger one $10\frac{1}{2}$ inches square, laid at the top and bottom. In room 52 adjoining, was another hypocaust, communicating with a larger one by an arch of brick. The area No. 1 was in another examination found to be surrounded by an inner wall, which appeared to have formed a kind of portico; and an entire column was found resembling the fragments found before, which showed that it had been surrounded by a colonnade. A cold bath was also found in the apartment marked 21. Mr. Lysons thinks the villas to have been the residence of a *proprætor*, or at least of the legate or governor of the province. At the time Mr. Lysons first communicated an account of this villa to the Archæologia, the discovery was confined to the rooms marked No. 1 to 26. During the years 1816 and 1817, by tracing the foundations of the walls on the east and west sides of the great court, it was discovered that the cryptoporticus extended all round. The western cryptoporticus 46, was 8 feet wide and 108 long, including a small room 45, at the north end, which had a mosaic pavement. Several rooms, No. 27, 51, 52, 53, 54, 55, 56 and 57. besides the cryptoporticus and passages, were discovered on the western side of the great court, most of them extending into an arable field belonging to the rector of Bignor. No remains of pavements were discovered in this division of the building, except those in the cryptoporticus above mentioned, and some fragments of the coarser kind in the rooms No. 28 and 29. Many large tesseræ were found among the rubbish in the passage No. 50. By digging further to the eastward of the single wall mentioned in the former account, that wall was ascertained to be part of an Eastern cryptoporticus. Nos. 60 and 61, which completed the enclosure of the great court, and the foundations of the buildings, were discovered in a field called the Loure-field, extending 181 feet eastward. Nos. 62 to 71.; several of these buildings were of large dimensions, and they were enclosed within a boundary wall of considerable thickness, not built at right angles with the eastern side of the principal court, but in a very irregular manner, the following being the dimensions of the several sides of this court, viz.: the eastern side 277 feet 4 inches; the west side 385 feet 5 inches; the north side 286 feet; and the south side 322 feet 8 inches.

It would appear reasonable to suppose that the Britons must have advanced considerably in the civilized arts of life, by such examples of Roman luxury as were afforded in their larger residences, such as that above described, for although

not equal to those in Rome, it is evident that they were of considerable dimensions, and decorated with taste and skill, in proof of which we have only to refer to the mosaics and paintings. Whether, however, the Britons did not profit by such examples; or whether they were prevented by external circumstances from turning their increased skill and knowledge to practical account, it is tolerably certain that they did not improve so much in these matters as they might reasonably be expected to have done.

It is true, that after the departure of the Romans, they were fully employed in resisting the attacks of their rougher neighbours, and probably had but little time for cultivating the arts of peace. They cannot have made much progress in house-building before the arrival and successful invasion of the Saxons; for had they, we should certainly look for some proof of it in the erections of their invaders, and this we do not find. Most of their churches and cathedrals, or at least of the earlier ones, seem to have been constructed of timber, and we cannot therefore suppose that their domestic buildings were erected in a more durable or costly manner. William of Malmsbury speaks of them as "low and mean dwellings;" they were probably constructed of wood, and roofed with reeds and straw. But even in Norman times, and for some period after the Conquest, there seems to have been but little progress made in this respect. The principal buildings erected for habitation immediately after the conquest of the Normans, consisted of small round towers raised on a mound, and designed with an eye to security rather than convenience. Located in an enemy's country, and in the midst of men who, although conquered in battle, were nevertheless impatient of their victors' control, and unsubdued in courage, it became a matter of necessity to secure themselves against the contingency of a sudden attack, and William found it a matter of policy to promote the erection of fortified residences by his followers. The earliest buildings of this kind were simple towers, either round, rectangular, or polygonal in plan, and of small size, but of considerable strength, the walls being sometimes as much as 12 feet in thickness, while the external diameter of the entire building did not measure more than from 40 to 50 feet. The windows and apertures were very narrow, and the entrance raised several feet above the ground, and approached by a steep flight of steps. Such a building is the keep at Conisborough, erected about this time. It is circular in plan, about 90 feet in height, which is divided into three stories, the lowermost, which is lighted only from the interior, being used probably as a dungeon; the next, in which is the entrance, as a storeroom; and the upper ones, for residence. The interior diameter, in this instance, is about 23 feet, and the thickness of the walls from 10 to 13 feet. At a somewhat later period, such towers or keeps were surrounded by a court enclosed within a strong wall and ditch, the former being strengthened by towers at intervals, and the latter crossed at the entrance by a drawbridge, which was defended by an advanced outwork or watch-tower, termed the barbacan. In such castles the keep was not used as a place of residence, except in cases of danger or emergency, more convenient and roomy apartments being provided in the towers or court-yard.

We next arrive at the Edwardian castles, which present an improved appearance. The keep was now dispensed with, the castle being still strongly fortified by an outer wall, with towers at intervals; but greater attention seems to have been paid to convenience and domestic comfort; and the buildings begin to assume the character of a fortified residence rather than of a mere stronghold: strength is evidently not the only property considered, although still a necessary qualification. Caernarvon castle is a good example of this date.

During the fourteenth century, the sterner features of castles were considerably modified, and assumed a lighter and more peaceful appearance. The apartments were enlarged, and rendered at once more commodious and agreeable. The apertures of the windows also were considerably enlarged, and, late in the period, filled with tracery in the heads. Examples exist at Windsor, Warwick, and Kenilworth.

It must not be forgotten, however, that during all this time there was in existence a different class of dwellings of a less imposing character, but perhaps more strictly entitled to the appellation of domestic buildings. They are included under the general term of *manor houses.*

Previous to the thirteenth century, houses were built of timber, and at first only of one story, being somewhat in the form of the inverted hull of a ship, formed of timber framework, the intervals being filled in with horizontal planks. Afterwards, this hull was raised on walls, likewise of timber frame-work filled up with clay, stones, and plaster. Stowe says that the houses in London of this period were not more than 16 feet in height; built of wood, and covered with reeds and straw. The general plan seems to have been that of a parallelogram, and where there were two stories, the approach to the upper was by an external staircase. The lower story was vaulted, and lighted by small windows; but there does not appear to have been any convenience for warming, except in the upper floor, where there is a hearth in the middle of the floor with smoke-hole above: the windows also of the upper floor were larger than those below. In some instances, the building was surrounded by a moat. An example of this kind exists at Boothby Pagnel, Lincolnshire. In some houses of the same date, the principal feature was the hall, which extends the whole height of the building, and is sometimes divided into aisles similar to those of a church, as in the palace of the bishop of Hereford.

In the thirteenth century the same general plan was preserved; but at its close, some little differences occur, as at Little Wenham Hall, Suffolk, where, above the general range of building, which is two-storied, one portion is carried up an additional story, so as to present externally the appearance of a tower. In this example, the lower portion of the building is constructed of flint and stone, and the upper part of brick—a material not found in any previous example, and not generally used for a considerable time afterwards. Square towers were common additions to the houses of the next century, the plans of which were more varied than those of preceding periods. The Mote, Ightam, Kent, is an example of this date; it is square on plan, and surrounded by a moat. Timber houses of this date exist at York and Salisbury, with ornamental barge-boards, which appear to have been introduced about this time, as were also dormer windows and chimney-shafts.

In the fifteenth century, the erection of castles, as distinguished from manor-houses, may be said to have ceased; the two were merged together, as it were; for although the dwellings were still fortified, they were incapable of a regular siege, as comfort was no less considered than security. Houses were erected of all shapes and materials, and often considerably oramented. The square plan, amongst others, was still in use, as was also the surrounding moat, although the latter was not so frequent as formerly. Chimneys became common at this period, and several shafts were often connected into one stack. Panelled ceilings were now introduced, both of wood and plaster; and the windows became large, and highly ornamented; bay and oriel windows were common. The internal walls of large mansions were often painted, or hung with tapestry, and, towards the close of the century, lined with wainscot. Examples of this date are

Eton College, Eltham and Hampton-Court palaces, and Crosby-Hall. Timber houses, which have the spaces between the timbers filled with ornamented plaster, are also of this date. Brick came into very general use during this century.

During the commencement of the next century, the houses retained much the same character, although perhaps somewhat more enriched, and occasionally with some introduction of Italian work. Ere the close, however, the Italian style had become predominant, which gives a vast difference in the buildings of the sixteenth century. The ceilings of this last style were entirely of plaster, which is often highly enriched with carving. Ornamental staircases and galleries were first introduced at this period, but open balusters were not common at the first, the space below the hand-rail being filled up with plaster. Timber houses are still common, and often of good design, the intervals between the quartering being filled with bricks or plaster. Examples of this date are Wollaston-Hall, Nottinghamshire; Longleat, Wiltshire; the Quarries, Rochester; and Little Charlton House, Kent.

During the next century, the Italian style of building continued to prevail, the Gothic features gradually disappearing until they were entirely lost in the works of Inigo Jones, Vanbrugh, &c. Amongst the earlier works may be mentioned Audley End, Essex; Hatfield House, Herts; and Holland House, near London; and amongst the latter, the spacious mansions of Blenheim and Castle Howard.

In the earlier Domestic buildings of this country but little attention was given to comfort. For a very long period the houses were constructed of a timber framing, either covered with planks, or having the intervals between the parts of the framing filled in with clay. Such materials of course rendered the houses subject to frequent conflagrations; and in cities where the houses were closely packed together in narrow streets, such accidents were most destructive. A law was enacted by Richard I., that all houses in the city should be built to a certain height of stone, and covered with slate or tiles; and after the fire, which consumed the greater part of Oxford in 1190, the same precaution was adopted in that city; and in cases where the people were too poor to effect this, a high stone wall, built up between every fourth or fifth house, was deemed sufficient. In these cases, however, the stonework was only rough rubble-work. Brick was introduced from Flanders, and we do not find any instance of its employment in this country until the close of the thirteenth century at Wenham-Hall, where the lower part is of stone, and the upper story of brick. This material did not come into general use until the reign of Henry VI., at the early part of the fifteenth century, but before its close it was very much employed.

In the interiors, the walls were, in most cases, left bare, or sometimes painted or hung with arras or tapestry suspended on hooks three or four inches from the wall. This ornamentation, however, was seldom introduced but in regal mansions, or such as vied with them in splendour; they were by no means of frequent or common use, nor were probably employed at all till the fourteenth century. There was a splendid specimen of tapestry in Warwick Castle in 1344, and Chaucer, who lived a few years later, in describing his chamber, says—

> "All the walls with colours fine,
> Were paint both text and glose;"

The floors were either of earth or stone, but at a later period were rough-cast with plaster and pebbles, and the dais, or upper end of the hall, planked. They were strewed with straw, or leaves, even in royal residences, for we hear of parties holding lands of Edward I., on condition of providing straw for strewing the king's chamber in winter, and herbs in summer; and Fitzstephen tells us, that Thomas à Becket, when chancellor to Henry II., "had his hall strewed every day in the winter, with fresh straw or hay, and in the summer with rushes and green leaves fresh gathered, that such knights as the benches could not contain, might not dirty their fine clothes when they sat on the floor." From this we learn that such litter served for a seat even in great houses; it also served for a bed amongst a lower class of persons.

The fireplace was in the centre of the hall, where logs of wood were supported on dogs, the smoke being allowed to find its way as best it could, through an opening in the roof, which was usually covered with a small turret or lantern, the sides being left open, or filled with louvre-boards. There does not seem to have been any means of warming the smaller chambers, except by pans of charcoal. It is true, we find chimneys in Winwall House, which is supposed to belong to the twelfth century, but this is an unique specimen, and it is certain that they were not in use for a considerable period after that. At Rochester and Hedingham Castles also, we have examples, but the flues are carried up only a very short distance in the wall, and then turned out. Early examples of chimneys are found at Conway Castle, built by Edward I. in the middle of the thirteenth century, and at Kenilworth of about the same date. These, however, are but exceptions; chimney flues were not common in the fourteenth century.

Glass for windows does not seem to have been in use in any other than ecclesiastical buildings, until the time of Edward I., and then it was of very rare occurrence, to be found only in the halls of princes. The common practice adopted for the admission of light consisted in the insertion of louvre-boards in apertures at the upper part of the apartment, but these, although effectual to exclude the rain, were but little adapted to exclude the wind also. To this end another expedient was resorted to—oiled canvas or linen was stretched over the apertures, which was to a certain extent effectual for all requirements, and certainly a great improvement upon louvre-boarding. Glass did not come into general use for gentlemen's houses before the reign of Henry VIII., and we find Sir Thomas More, in his "Utopia," alluding to this circumstance, when he says, that they keep the wind off their houses with glass, for it is there much used, and some also with very fine linen dipped in oil or amber. That it was occasionally in use some time previous to this period, is evident from Chaucer's description of his chamber, for he says:—

> "With glas
> Were all the windowes well yglazed;
> Full clere, with not a hole ycrased;"

They were also beautifully painted, for he goes on—

> "That to behold it was great joy;
> For holly all the story of Troy
> Was in the glaising wrought."

Such were the comforts of our ancestors; we should scarcely call them by that name now-a-days, when the regal luxuries of former times are looked upon as necessaries even by our poorer classes. From the time of the Reformation, however, domestic convenience and comfort made rapid progress; we fear we might say too rapid, for the real happiness and welfare of the people. Belonging to the olden times, we find ecclesiastical structures, which, even in their present state of neglect and decay, rival the resources of modern taste and skill, while their domestic buildings were mean and

cheerless: we have lived to see the tables turned—churches mean, cold, and neglected; nay, even our old structures, the bequests of our ancestors, allowed to fall to ruin and decay, while our own dwellings are loaded with luxuries, and over-crowded with ornament. But this scandal is passing away, and we are glad to see some slight return to the principles of our forefathers.

For a further elucidation of this subject, as regards the Domestic buildings of Old England, we refer to the article on Tudor Architecture.

The dwelling-houses of the metropolis are divided by act of parliament into three classes, each of which is subject to certain regulations as regards the building, as is shown in the following table:—

If in height	If in area	If containing	The Raters.	The thickness of external walls must be		The thickness of party-walls must be		
more than 70 ft., and not more than 85 ft.	more than 10 sqrs., and not more than 14 sqrs.	7 stories	1st class	21½ in. from top of footing to underside of floor next but 3 below topmost floor,	and 13 in. thence to top of wall.	21½ in. from top of footing to underside of floor next but three below topmost floor,	and 17½ in. thence to underside of floor next below topmost floor,	and 13 in. thence to top of wall.
more than 85 ft.	more than 14 sqrs.	more than 7 stories.	extra 1st.	21½ in. from top of footing to underside of floor next but 2 below topmost floor,	and 17½ in. thence to top of wall.	21½ in. from top of footing to underside of floor next but three below topmost floor,	and 17½ in. thence to underside of topmost floor,	and 13 in. thence to top of wall.
more than 52 ft., and not more than 70 ft.	more than 6 sqrs., and not more than 10 sqrs.	6 stories.	2nd.	17½ in. from top of footing to underside of floor next but 1 below topmost floor,	and 13 in. thence to top of wall.	17½ in. from top of footing to underside of floor next but one below topmost floor;	13 in. thence to top of wall.	
more than 38 ft., and not more than 52 feet.	more than 4 sqrs., and not more than 6 sqrs.	5 stories.	3rd.	17½ in. from top of footing to underside of floor next but 2 below topmost floor,	and 13 in. thence to top of wall.	17½ in. from top of footing to underside of floor next but two below topmost floor;	13 in. thence to underside of topmost floor,	and 8½ in. thence to top of wall.
not more than 38 feet.	not more than 4 sqrs.	not more than 4 stories.	4th.	13 in. from top of footing to underside of floor next below topmost floor,	and 8½ in. thence to top of wall.	13 in. from top of footing to underside of floor next but one below topmost floor,	and 8½ thence to top of wall.	

HOUSING, the space excavated out of a body, for the insertion of some part of the extremity of another, in order to fasten the two together: thus the string-board of a stair is most frequently excavated, or notched-out for the reception of the steps. The term is also applied to a niche for containing a statue.

HOVELLING, a method adopted for the prevention of smoky chimneys by carrying up the two sides which are the most obnoxious to currents of air, above the others; or by leaving apertures on all sides for the escape of the smoke.

HUE (from the Saxon) in painting, any degree of strength or vividness of colour, from its greatest or deepest, to its weakest tint.

HUMERI, the angles of a temple formed by the longitudinal and transverse walls of the cella.

HUNDRED OF LIME, a denomination of measure, in some places denoting 35, and in others 25 heaped bushels or bags.

Hundred, *Great* or *Standard*, = 112lb. avoirdupoise = 4 quarters = 7 stone (of 16lb.) = 14 cloves (8lb.) = 16 cloves (7lb.) = 1,792 ounces = 20,972 drachms avoirdupoise = .93333 long cwt. (120lb.) = 103lb. 2½ oz. Dutch, or Scottish weight. This is the legal hundred-weight of the custom-house of London, and in all the southern parts of England.

Hundred, *Long*, or *Northern*, = 120lb. = $8\frac{4}{7}$ stones (14lb.) = 12 rationes (10lb.) = 1.0714286 great cwt. (112lb.) This weight is legalized on all or most of the canals and navigable rivers in the north of England and of the midland counties, by their acts for collecting tolls, &c.

Hundred is also used as a measure to express a certain quantity or number of things.

Deal boards are sold at six score to the hundred, called *the long hundred*. Pales and laths are counted at five score to the hundred if five feet long, and six score if three feet long.

HUNG, *Double*, see Double Hung.

HUNTING TOWERS, ancient buildings erected, as is supposed, for the purpose of giving ladies an opportunity of viewing the progress of the chase. Examples remain at Chatsworth, and at Tibbermuir near Perth, in Scotland.

HURLERS, a name given to a rude erection of stones existing near St. Clare, Cornwall. They are of Druidical origin. *See* Celtic Architecture.

HURRIES, in engineering, is sometimes applied, at Newcastle and other places, to the strong stages of wood erected on the sides of navigable rivers and harbours, to which the railways are conducted from the coal pits; by which means the load is emptied at once, by the help of a spout, from the railway waggons into the holds of ships.

HUT (from the Saxon *hutte*) a small cottage or hovel. It is also used for the soldiers' lodges in the field, otherwise called *barracks* or *caserns*.

HUT, in rural economy, a low sort of building, of the cottage kind, generally constructed of earthy materials, as strong loamy clay, &c. A number of huts of this description have been built on the borders of the South Esk, in Scotland, which have a very neat and rural appearance, affording the idea at a distance of their being formed of a kind of brown brick-work. The materials employed consist of a sort of muddy clay, blended with the roots of aquatic plants, which are dug beyond the flood-mark of the river, in such sizes and shapes as are suitable for the intended purpose. The pieces, or peats, as they are called, are generally cut out in the form of bricks, but somewhat larger, being prepared in every respect in the manner of peat-fuel. It is useful in some cases to build huts with lime-mortar, but more commonly with clay only.

These huts are generally preferred by the cottagers to such as are built of stone, being warmer, and nearly as durable.

It seems not improbable but that a similar sort of material for building this kind of cottages may be met with in many situations where it has not yet been discovered, and be made use of in this way, as well as for various fences of the wall kind.

HYPÆTHRAL TEMPLE, see the following article.

HYPÆTHRON, or Hypæthros (from the Greek, *open above*) a temple with ten columns on the pronaos and posticus, in external appearance similar to the dipteral; but within, it had a double tier of columns on each side, detached from the wall, and the middle area was open to the sky. The cell was approached from both front and rear. From the description given by Vitruvius, it appears, that Rome did not afford

any example of this species; and he points out the temple of Jupiter Olympus at Athens as one.

HYPERBOLA (from ὑπερ and βάλλω) one of the conic sections, being that which is made by a plane cutting the opposite side of the cone produced above the vertex, or, by a plane which makes a greater angle with the base than the opposite side of the cone makes. In this figure the squares of the ordinates are greater than, or exceed, the rectangles under the parameters and abscissas, whence the name *hyperbola*.

A few useful properties of the hyperbola.—1. The squares of the ordinates of any diameter are to each other, as the rectangles of their abscissas.

2. As the square of any diameter is to the square of its conjugate, so is the rectangle of two abscissas to the square of their ordinate.

3. The distance between the centre and the focus, is equal to the distance between the extremities of the transverse and conjugate axes.

4. The difference of two lines drawn from the foci to meet in any point of the curve, is equal to the transverse axis.

5. All the parallelograms inscribed between the four conjugate hyperbolas, are equal to each other, and each is equal to the rectangle of the two axes.

6. The rectangles of the parts of two parallel lines, terminated by the curve, are to each other as the rectangles of the parts of any other two parallel lines, anywhere cutting the former. Or, the rectangles of the parts of two intersecting lines are as the squares of their parallel diameters, or squares of their parallel tangents.

7. All the parallelograms are equal which are formed between the asymptotes and curve, by lines parallel to the asymptotes.

For other properties, see the articles CONE, and CONIC SECTION.

HYPERBOLA, *Acute*, one whose asymptotes make an acute angle.

HYPERBOLA, *Ambigenal*, that which has one of its infinite legs falling within an angle formed by the asymptotes, and the other falling without that angle.

HYPERBOLA, *Apollonian*, the common hyperbola, as derived from the cone. See HYPERBOLA.

HYPERBOLA, *Deficient*, a curve having only one asymptote, though two hyperbolic legs running out infinitely by the side of the asymptote, but contrary ways.

HYPERBOLA, *Equilateral*, has its asymptotes equal to each other.

HYPERBOLAS, *Infinite*, or HYPERBOLAS OF THE HIGHER KINDS, are expressed or defined by general equations similar to that of the conic or common hyperbola, only having general exponents, instead of the particular numeral ones, but so that the sum of those on one side of the question is equal to the sum of those on the other side. Such as $a\,y^{\,m+n} = b\,x^m\,(d + x)^n$, where x and y are the abscissa and ordinate to the axis or diameter of the curve; or $x^m\,y^n = a^{m+n}$, where the abscissa x is taken on one asymptote, and the ordinate y parallel to the other.

HYPERBOLIC CONOID, a solid formed by the revolution of an hyperbola about its axis; it is otherwise called HYPERBOLOID, which see.

HYPERBOLIC CURVE, the same as the hyperbola. To draw a tangent to any point in the hyperbolic curve, draw a semi-diameter to the given point, and find its conjugate; then through the given point, draw a straight line, parallel to the conjugate diameter; which line will be a tangent to the curve.

To find the focus of the hyperbolic curve, take the distance between the extremities of the transverse and conjugate axes, and apply it from the centre upon the axis, and the remote extremity of the distance gives the focus.

HYPERBOLIC CYLINDROID, a solid formed by the revolution of an hyperbola about its conjugate axis, or line through the centre perpendicular to the transverse axis.

HYPERBOLOID, a conoid formed by the revolution of an hyperbola about its axis. It is otherwise called an *hyperbolic conoid.*

To find the solidity of an hyperboloid, or the frustum of an hyperboloid.—To the areas of the two ends, add four times the area of the middle section parallel thereto, and multiply the sum by one-sixth part of the axis or height, and the product is the solidity. In the complete hyperboloid, the area of the end at the apex being nothing, the rule will be similar to what is laid down under the article CONOID.

An hyperboloid is to a paraboloid of the same base and altitude as $t + \dfrac{2x}{3}$ is to $t + x$.

$$\text{Let } \left.\begin{aligned} t &= \text{the transverse} \\ c &= \text{the congugate} \end{aligned}\right\} \text{axes of the generating hyperbola.}$$

$$\begin{aligned} x &= \text{the abscissa or altitude of the solid.} \\ y &= \text{the ordinate or radius of the base.} \\ p &= 3.1416. \end{aligned}$$

$$\text{Then } y^2 = c^2 \times \frac{t\,x + x^2}{t^2}, \text{ by the property of the solid;}$$

$$\text{and } p\,y^2\,\dot{x} = p\,c^2\,\dot{x} \times \frac{t\,x + x^2}{t^2}, \text{ the fluxion of the solid;}$$

$$p\,y^2\,x = p\,c^2\,x^2 \times \frac{\frac{1}{2}\,t + \frac{2}{3}\,x}{t^2}, \text{ the fluent of the solid;}$$

$$\text{but because } y^2 = c^2 \times \frac{t\,x + x^2}{t^2}, \text{ we obtain } c^2 = \frac{y^2\,t^2}{t\,x + x^2}.$$

Therefore, substituting $\dfrac{y^2\,t^2}{t\,x + x^2}$ for c^2 in the fluent $p\,c^2\,x^2 \times \dfrac{\frac{1}{2}\,t + \frac{2}{3}\,x}{t^2}$ we obtain $\dfrac{p\,y^2\,x}{2} \times \dfrac{t + \frac{2}{3}\,x}{t + x}$ = half the area of the base multiplied into the altitude, $\times \dfrac{t + \frac{2}{3}\,x}{t + x}$, for the solidity of the solid. But the paraboloidal area is half the area of the base multiplied into the altitude; that is, $\dfrac{p\,y^2\,x}{2}$; now $\dfrac{p\,y^2\,x}{2} \times \dfrac{t + \frac{2}{3}\,x}{t + x} : \dfrac{p\,y^2\,x}{2} : : t + \frac{2}{3}x : t + x$; and hence the proposition is manifest.

HYPERTHYRUM, the lintel of a doorway, or that part of the frame which stands over the supercilium. In Grecian buildings it consisted of a frieze and cornice, the latter supported by a console at each extremity.

HYPOCAUSTUM, (from ὑπο *under*, and *καυϛον to burn*,) among the Greeks and Romans, a subterraneous place, in which was a furnace for heating the baths. Another kind of hypocaustum was a sort of kiln to heat their winter parlours.

Several hypocausts have been found amongst the Roman remains still existing in Britain. About three years since, the remains of a portion of a Roman villa were laid open in Lower Thames-street, London, and beneath the floor of one of the rooms was discovered a hypocaust formed of columns about two feet in height, each consisting of fourteen tiles about twelve inches square. These were connected at the top by larger tiles, which formed the superstructure of the floor. Flue-tiles, with varied patterns incised on their surfaces, were likewise found amongst the ruins, which originally conveyed warm air up the sides of the building.

More recently, a hypocaust was discovered at Cirencester, and in a most perfect condition, the furnace, which was in existence, still containing some portion of the fuel. In this case, the columns were of two kinds, square and circular, the former being composed of tiles laid one upon the other to the number of ten, and the latter being formed of blocks of stone. Resting upon these pillars were large square tiles, as in the preceding example, and above these a layer of concrete six inches in thickness, on which the pavement was laid. The room above the hypocaust measured twenty-five feet square, and it is remarkable that the hypocaust extended only half-way underneath, the remaining half of the pavement being laid solid.

Still more recently, the remains of some apartments have been found within a Roman camp at Lymne, Kent. An extensive hypocaust was discovered under the floor of these apartments, formed entirely of layers of large tiles placed at regular intervals, but the pavement had been totally destroyed. Several hollow flue-tiles were also discovered of a similar description to those above alluded to. These, in all probability, were connected with the hypocaust, and served to convey the hot air from the furnace through the principal apartments of the villa, the hypocausts being used not only for baths, as is by some supposed, but also in the place of fires, and answered an exactly similar purpose to our modern hot-air pipes.

In a hypocaust discovered at Lincoln some few years since, the piers supporting the pavement were all of the circular form.

HYPODROMUS, (Greek ὑπὸ, *under*, and δρομος, *from* τρεχέιν, *to run*,) amongst the Romans, a shady or covered walk or ambulatory.

HYPOGÆUM, (from ὑπο, *under*, and γῆ *the earth*,) in ancient architecture, a name given to all parts of a building that were underground.

The term was more particularly applied to the common sort of sepulchres used by the Romans; they were built underground, whence their name, and are now known under the name of catacombs. The urns containing the ashes of the deceased were placed round the chamber in niches cut out in the walls, which, from their resemblance to the niches of a pigeon-house, were called columbaria.

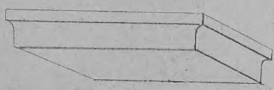
Montfaucon has given descriptions and illustrations of several such hypogæa in his *Antiquitè Expliquée*. In many examples, especially in those of later date, the chambers are highly ornamented.

HYPOPODIUM, (from ὑπο, *under*, and πȣ̃ς, *foot*,) a piece of furniture in the ancient baths, on which the feet rested.

HYPOSCENIUM, (from ὑπο, *under*, and σκηνὴ, *a scene*,) a partition under the logium appointed for the music.

HYPOTRACHELIUM, (from ὑπο, *under*, and τραχήλιον, *the neck*,) the lower part of the Tuscan and Doric capitals, comprehended between the astragal at the top of the shaft, and the fillet or annulets under the ovolo. This description applies only to the Roman Doric; for the Grecian, instead of an astragal, had from one to three horizontal grooves circumscribing the column.

END OF VOL I.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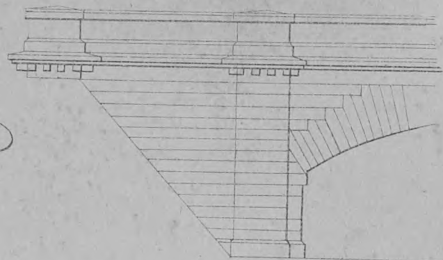
ABACUS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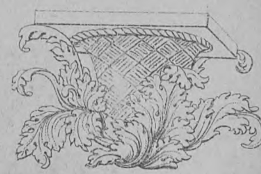
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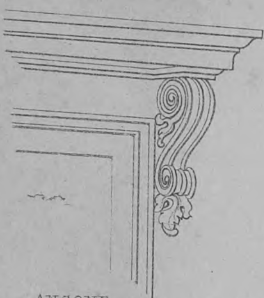
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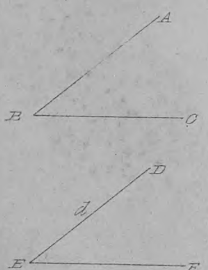

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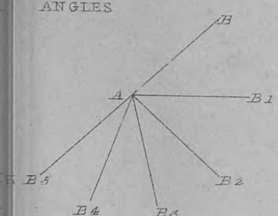

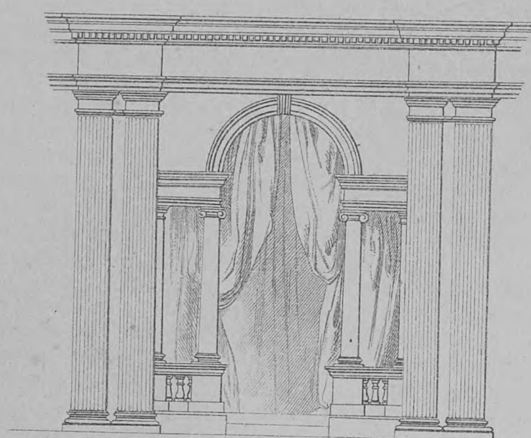
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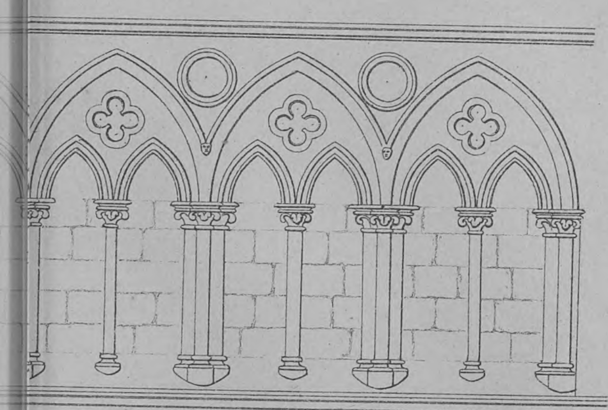
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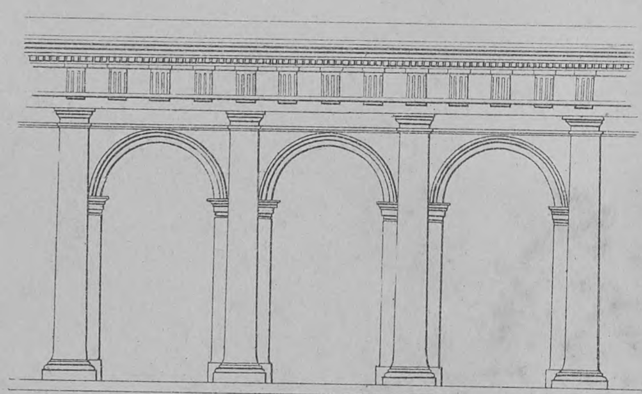
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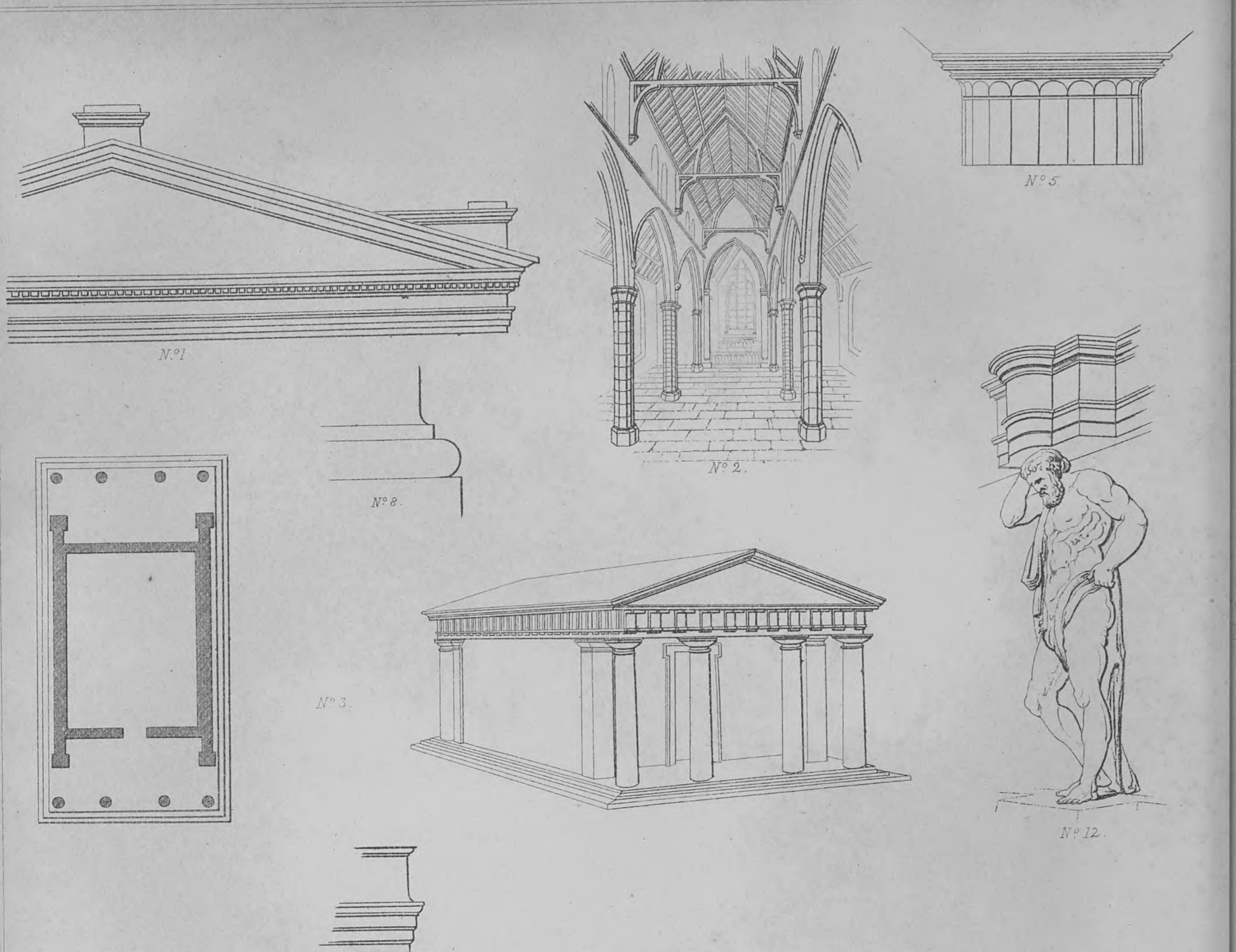
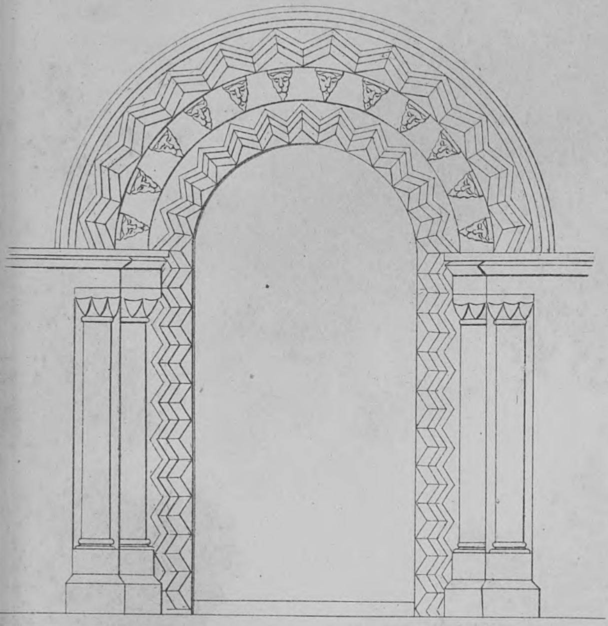


A. Gilbert. Eng.d by

N.° 1. Acroteria. N.° 2. Aisle. N.° 3. Amphiprostyle, Plan & Perspective view. N.° 4. Angular Capital. N.° 5. Annulets. N.° 6. Antæ Plan & Perspective view. N.° 7. Ante fixæ. N.° 8. Apophyge. N.° 9. Architrave. N.° 10. Archivolt. N.° 11. Attic. N.° 12. Atlantes.



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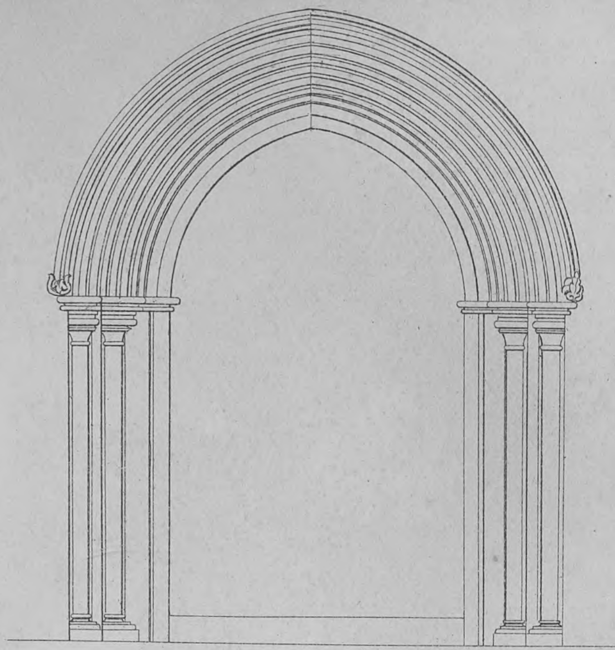

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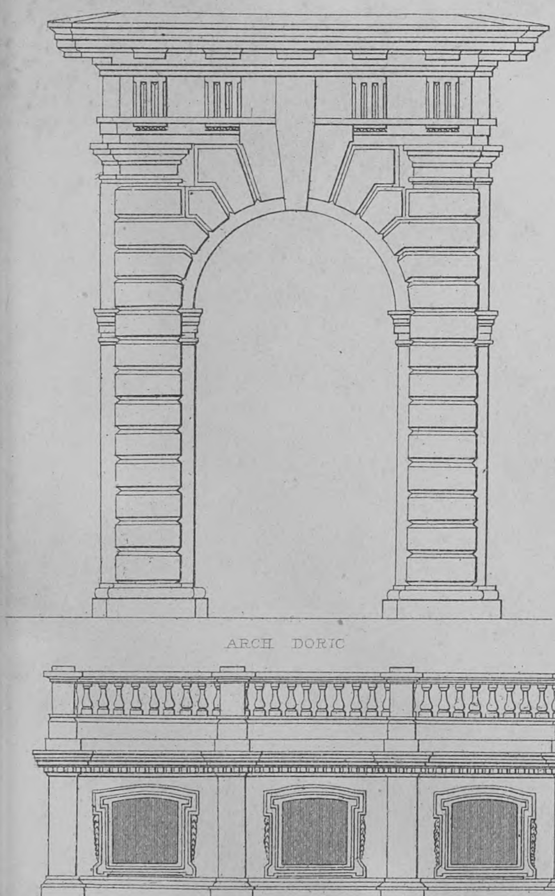

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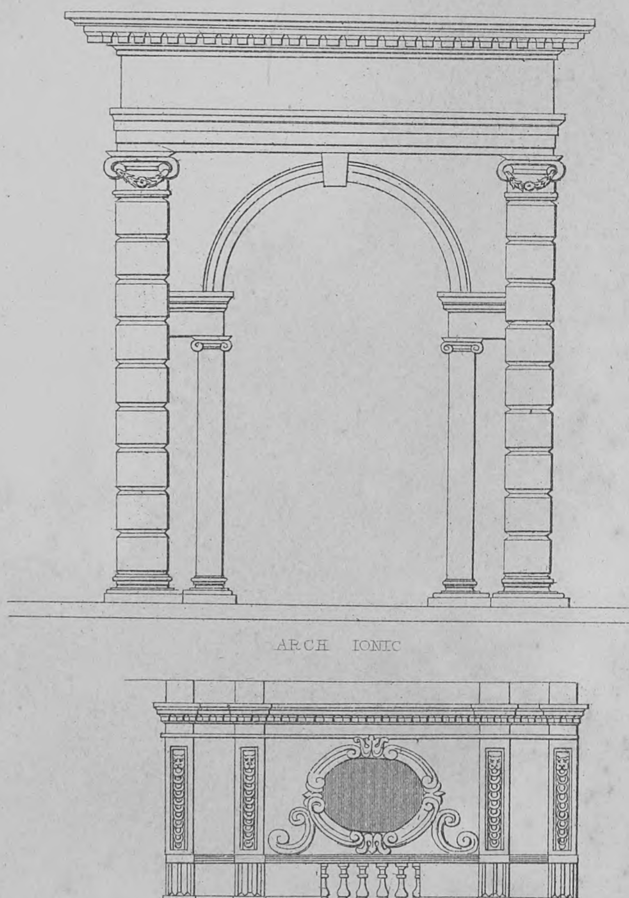

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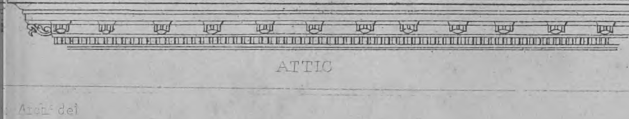

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Arch. del J. C. Buttre, sculp

BALUSTERS

PLATE I

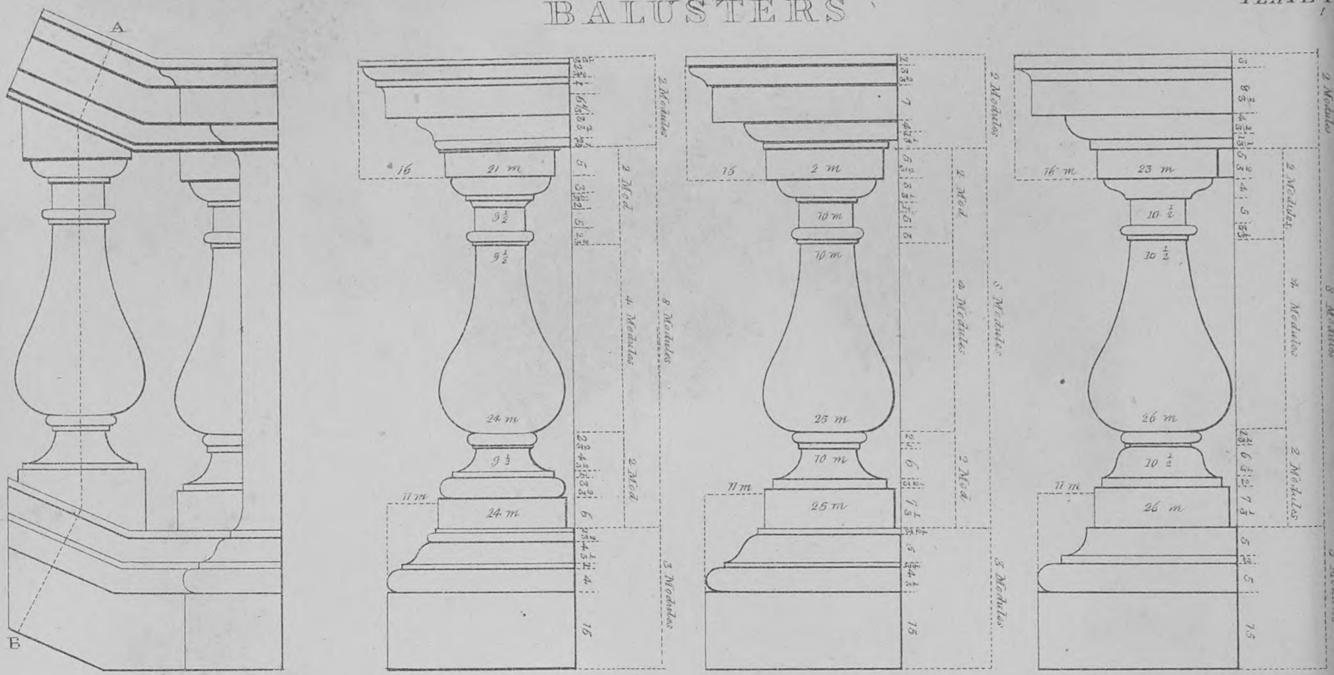
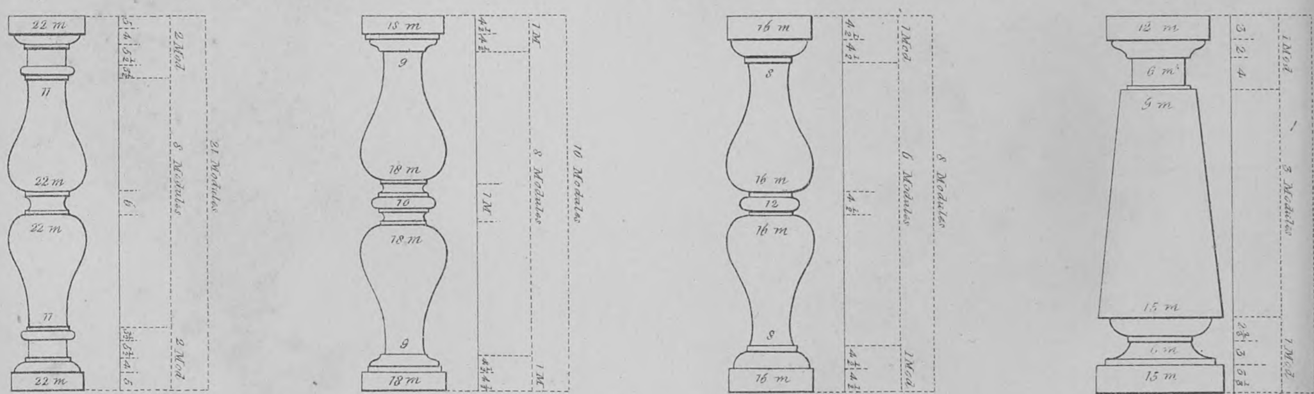
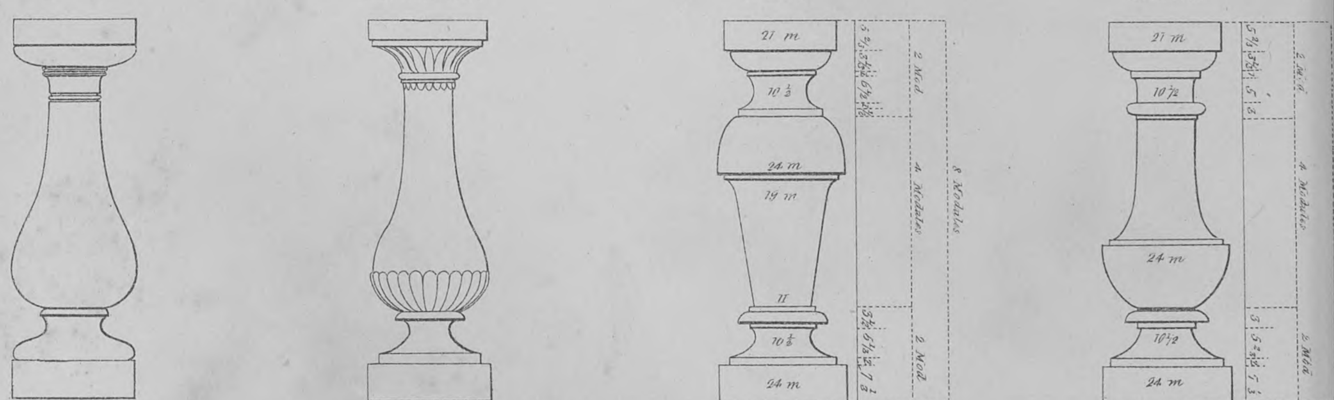


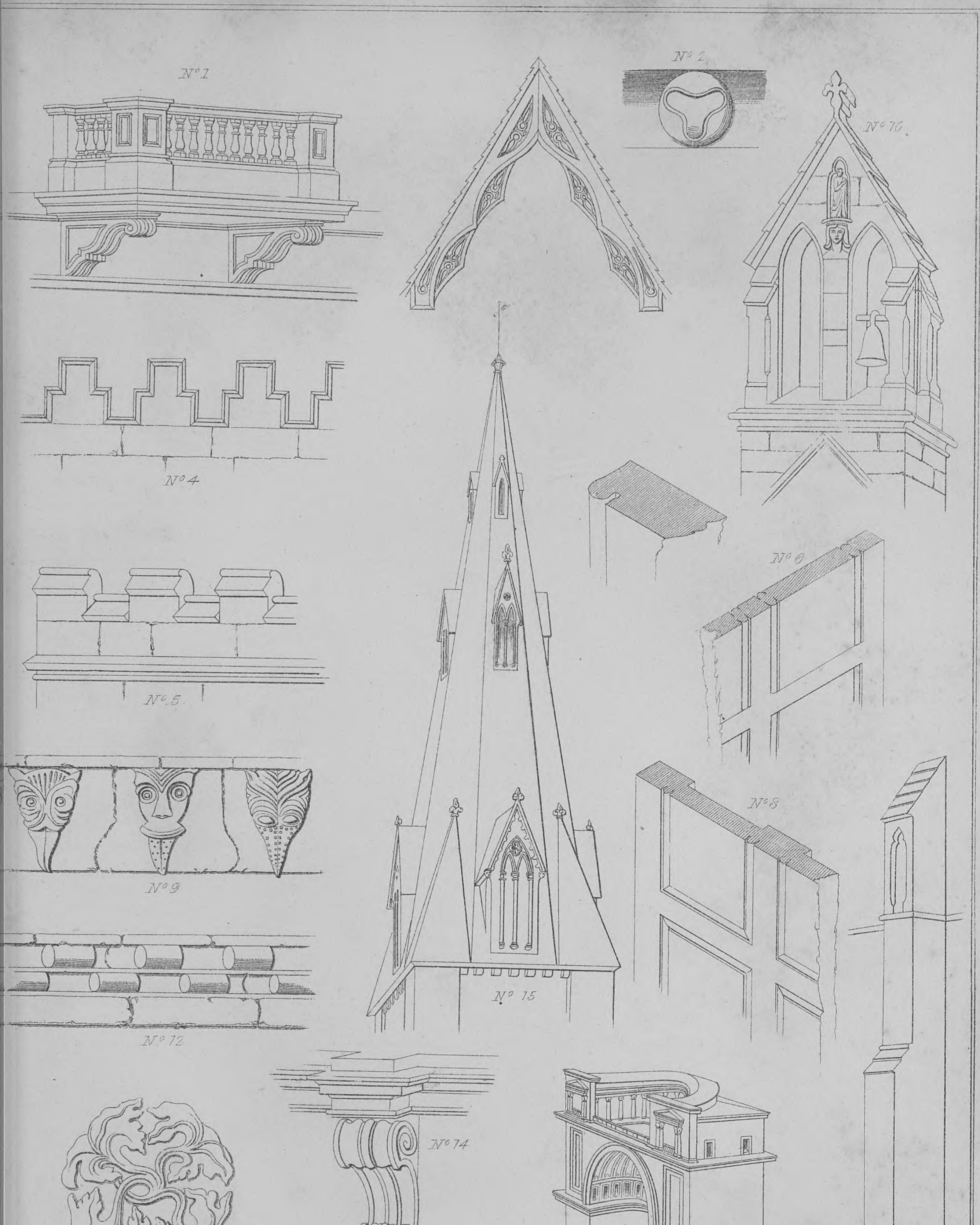
Fig. 1. — *Corinthian or Composite* — *Doric or Ionic* — *Tuscan*



Doric — *Corinthian* — *Doric* — *Tuscan*

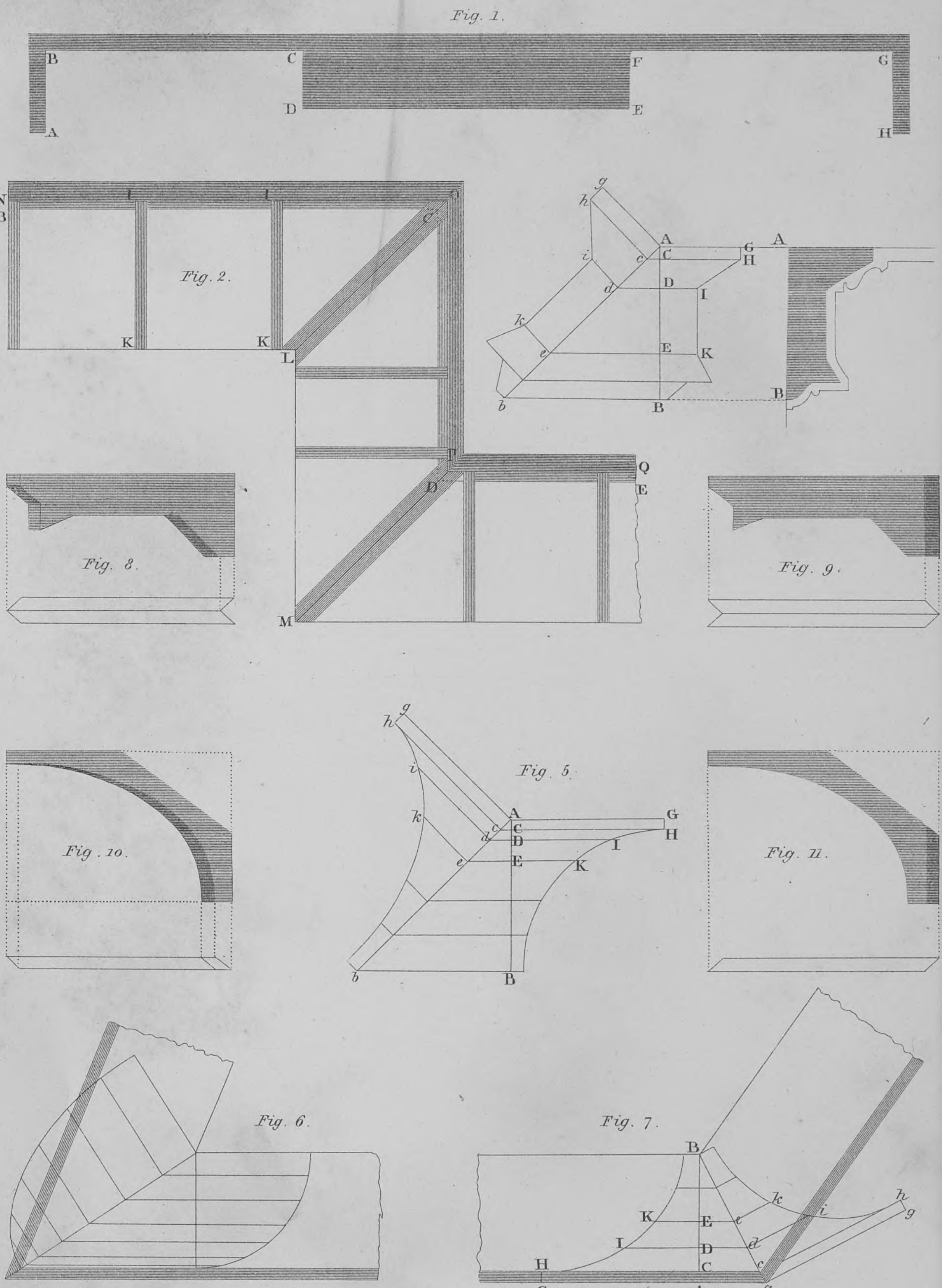


P. Nicholson. — R. Thew.



N° 1 Balcony	N° 5 Battlement	N° 9 Beak head moulding	N° 13 Boss
N° 2 Ball flower	N° 6 Bead & Butt	N° 10 Bell cot	N° 14 Bracket
N° 3 Barge boards	N° 7 Bead & quirk	N° 11 Belvedere	N° 15 Broach spire
N° 4 Battled embattled	N° 8 Bead, flush & square	N° 12 Billet moulding	N° 16 Buttress

BRACKETING.



Drawn by M. A. Nicholson.
Revised by Thos. J. Hay.

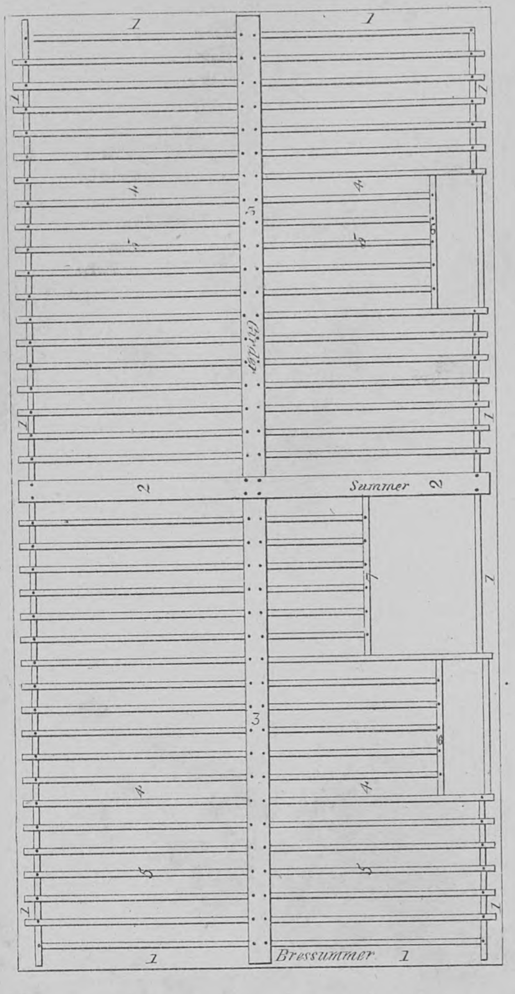
Engd. by R. Thew.

Gilbert

R. Thew sc.

PLATE I.

Fig. 1.



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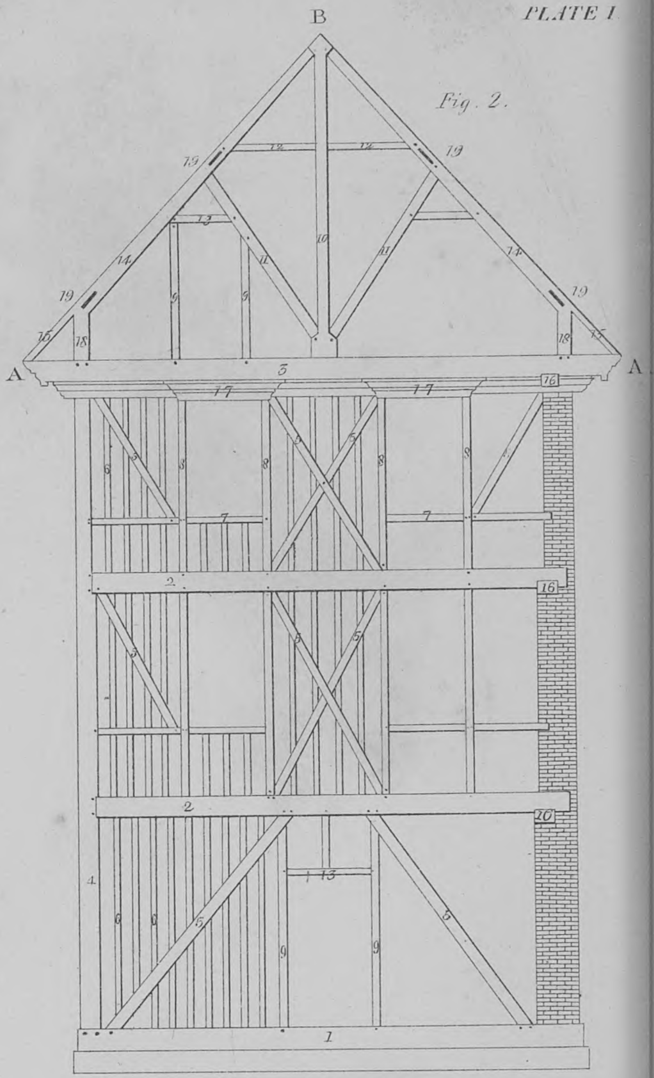


Fig. 3.

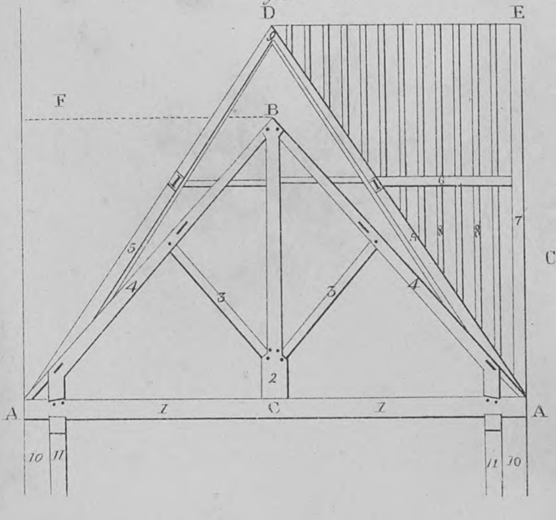
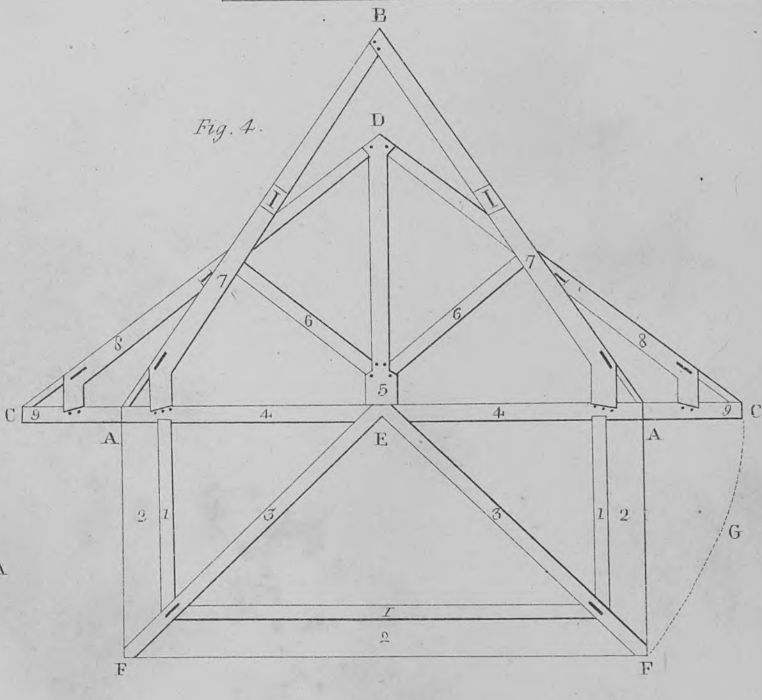
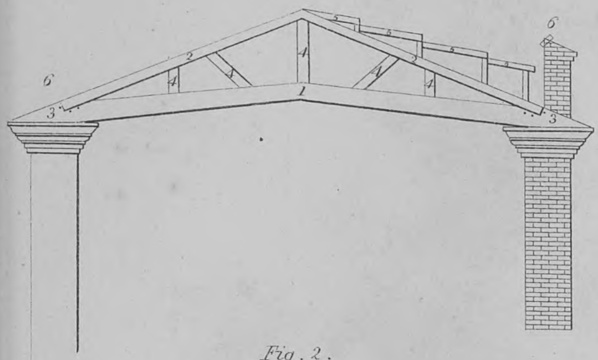


Fig. 4.



P. Nicholson. R. Thew.

Fig. 1.



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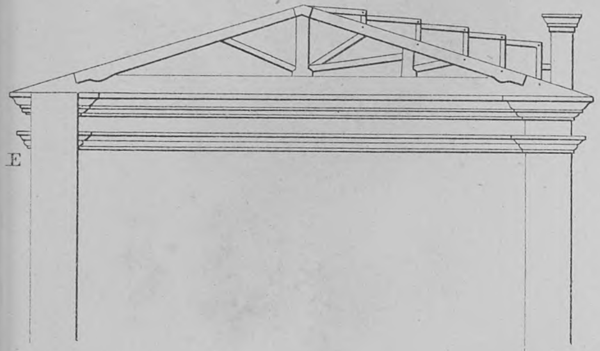

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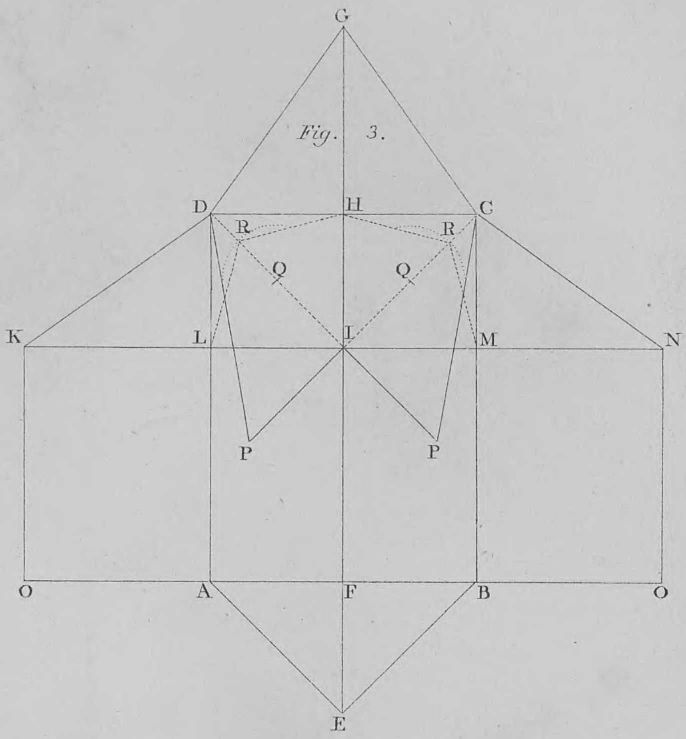

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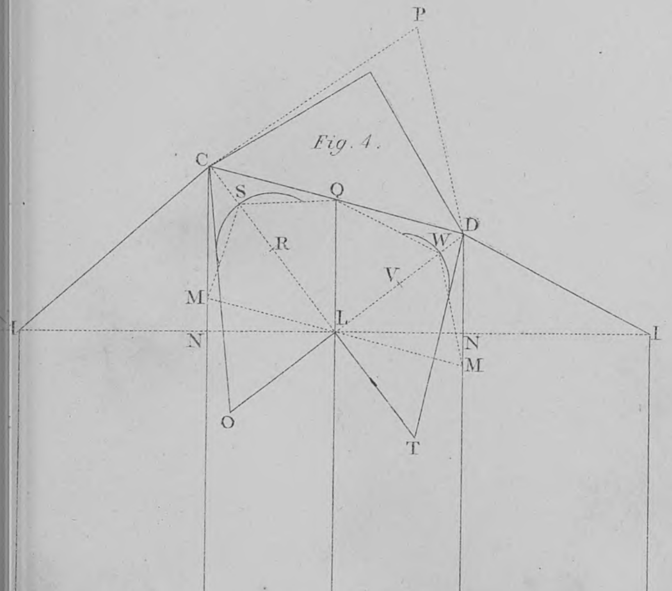

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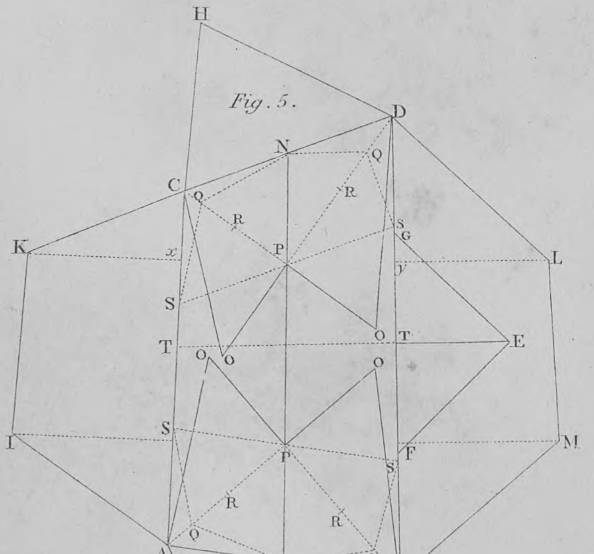
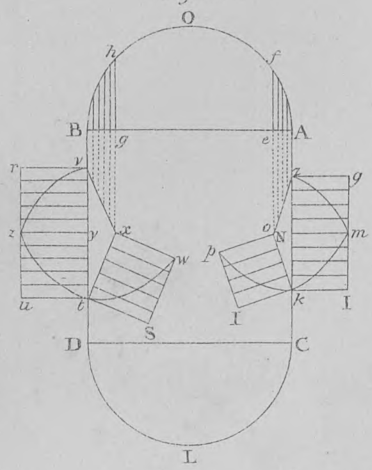


Drawn by P. Nicholson. Eng^d by R. Thew.

Fig. 4.



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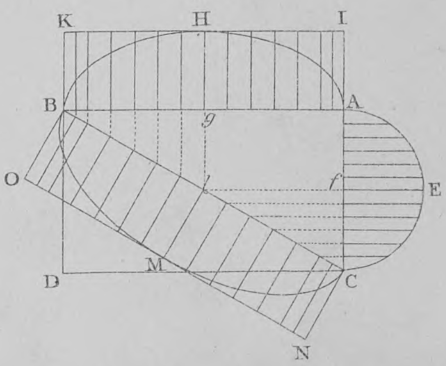

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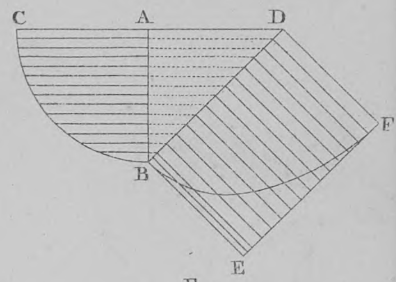
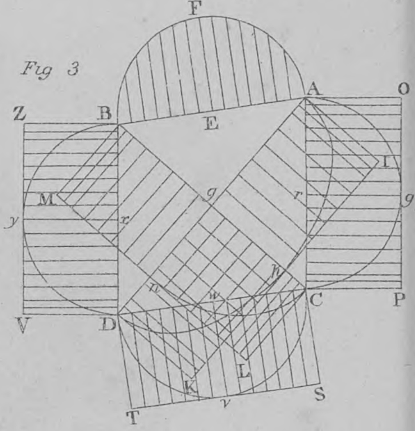
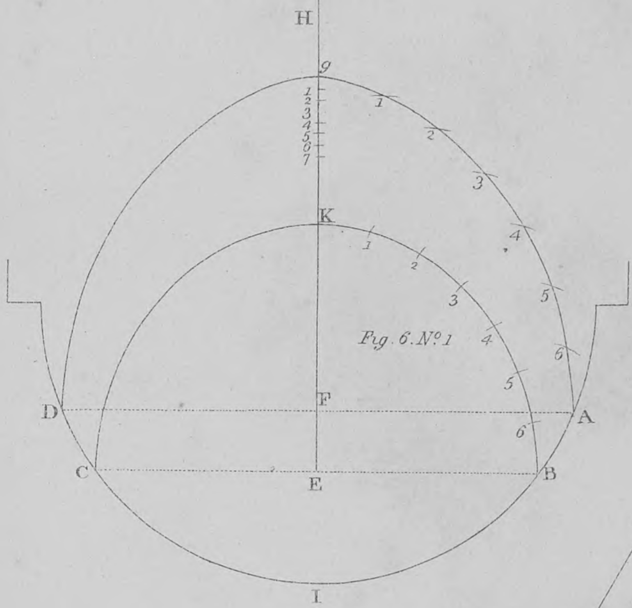
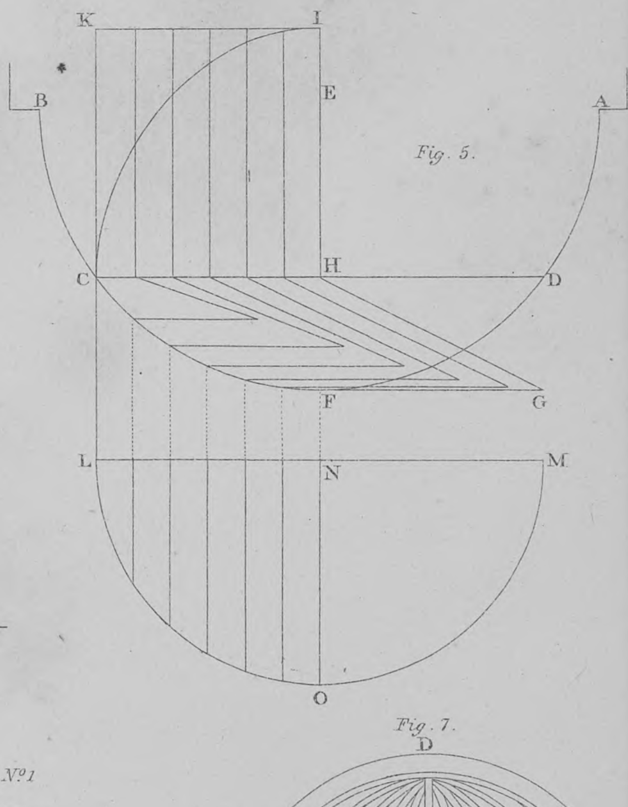


Fig 3







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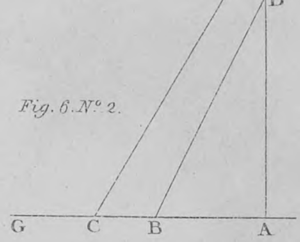

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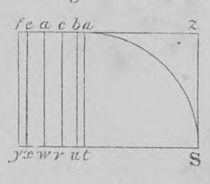

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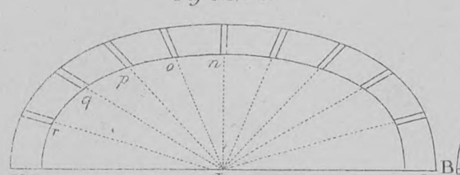

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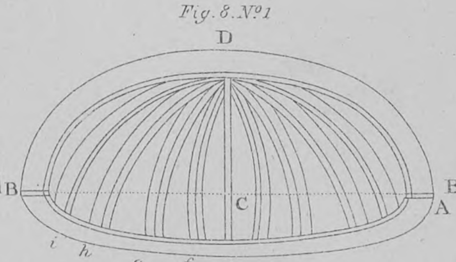

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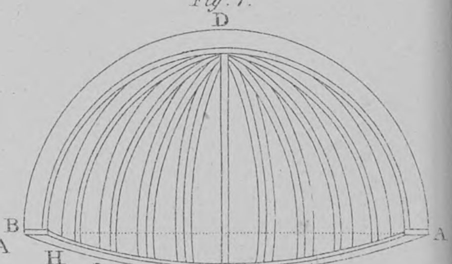

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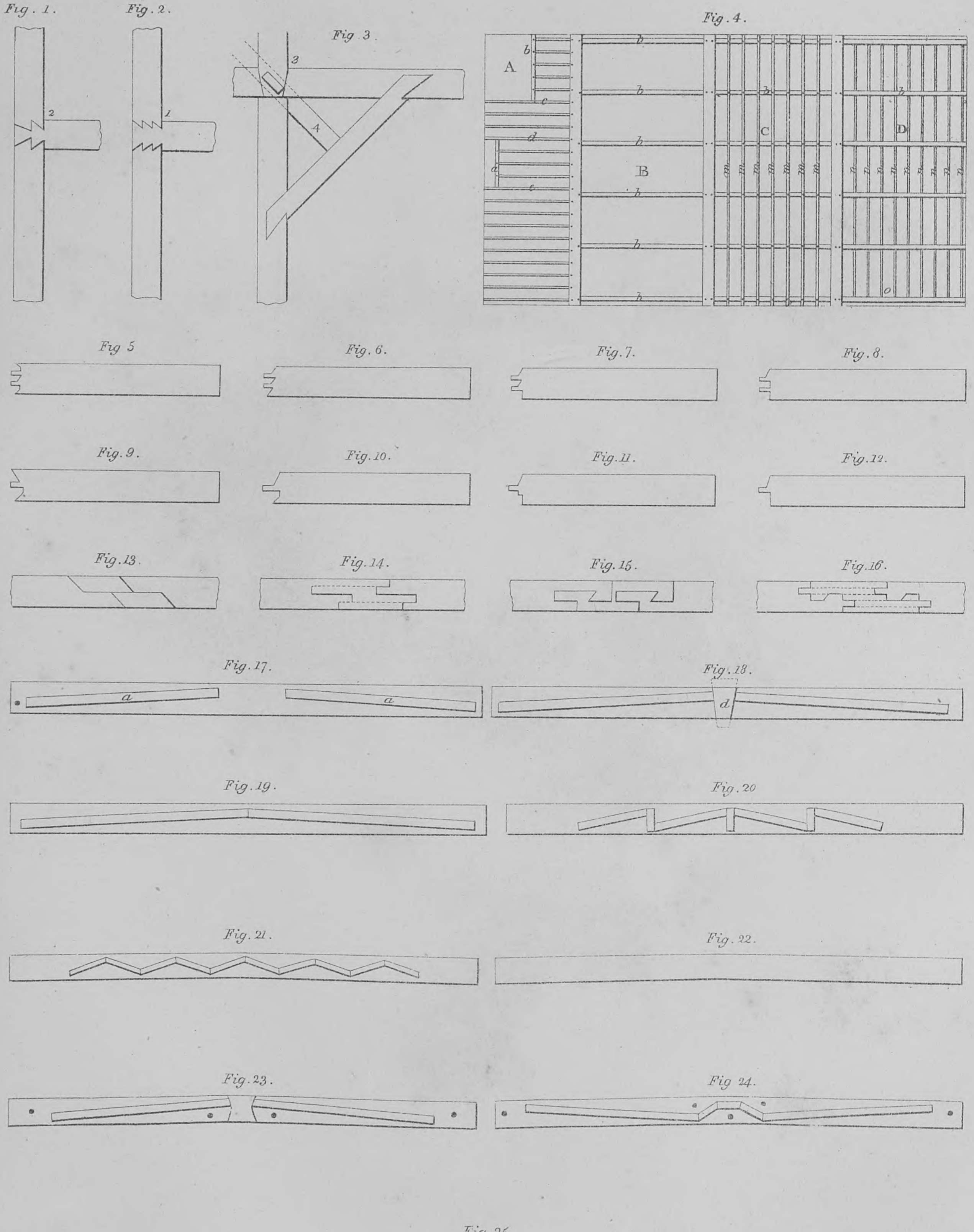
Engd. by R. Thew.

CARPENTRY.

PLATE IV.



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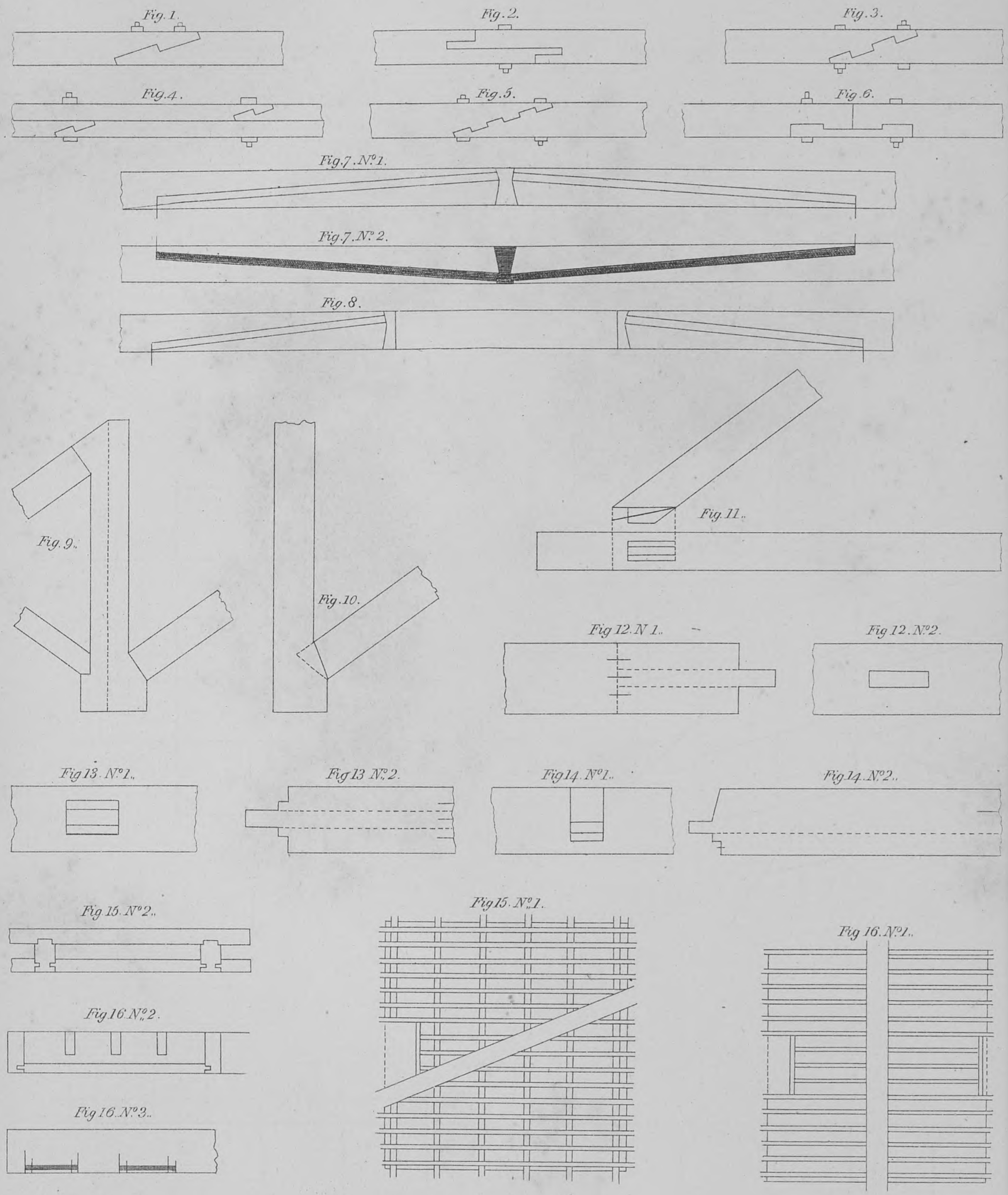
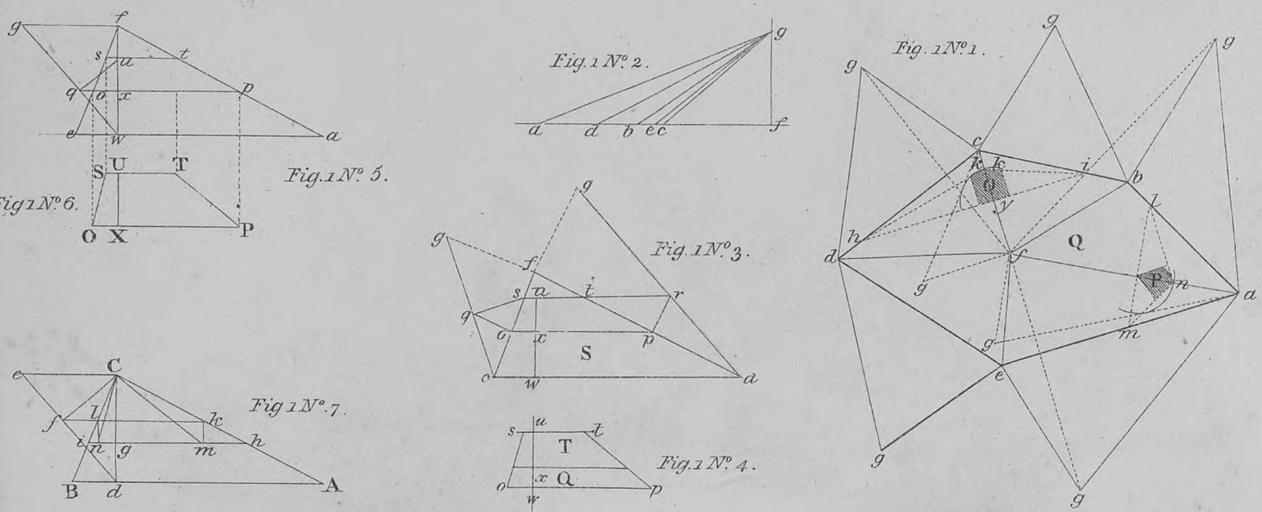


Drawn by P. Nicholson. Eng.d by R. Thew.



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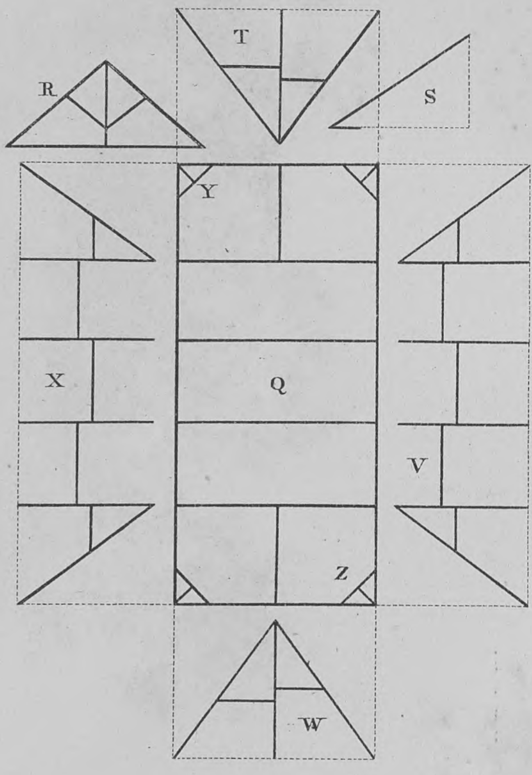

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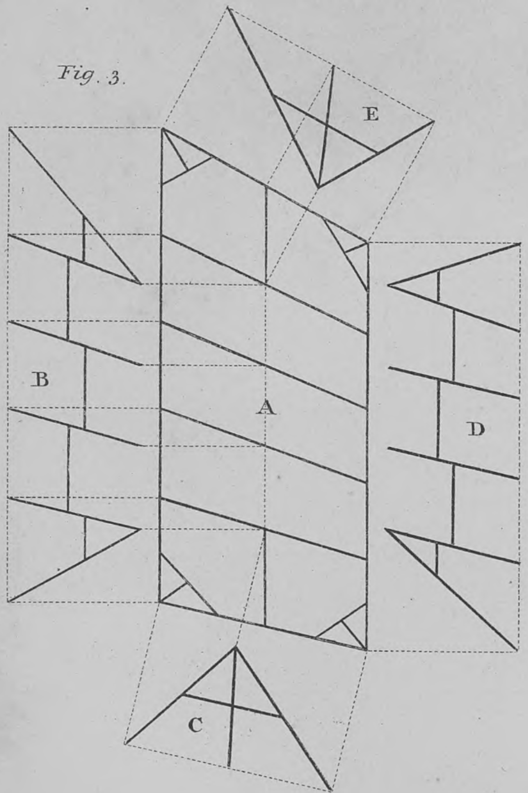

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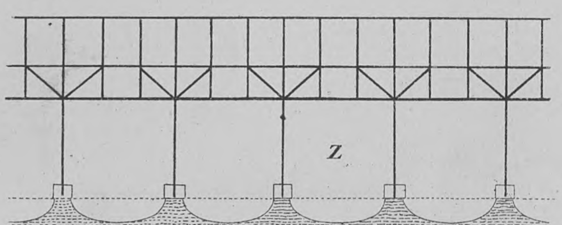

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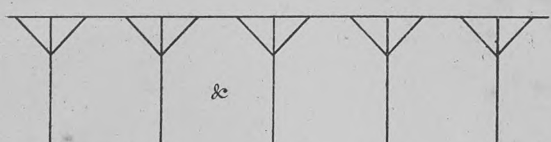
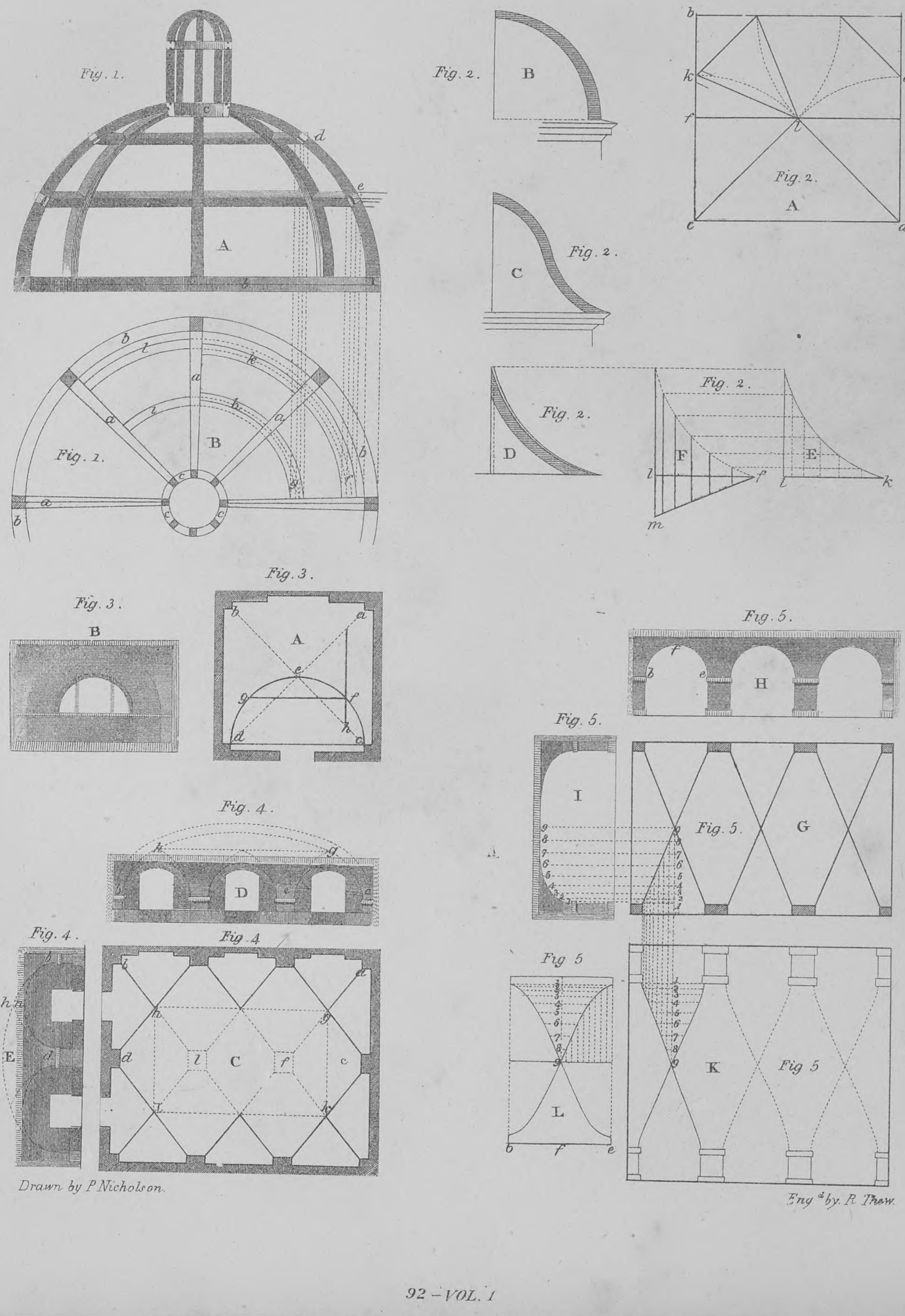


Drawn by P. Nicholson. Eng.d by R. Thew



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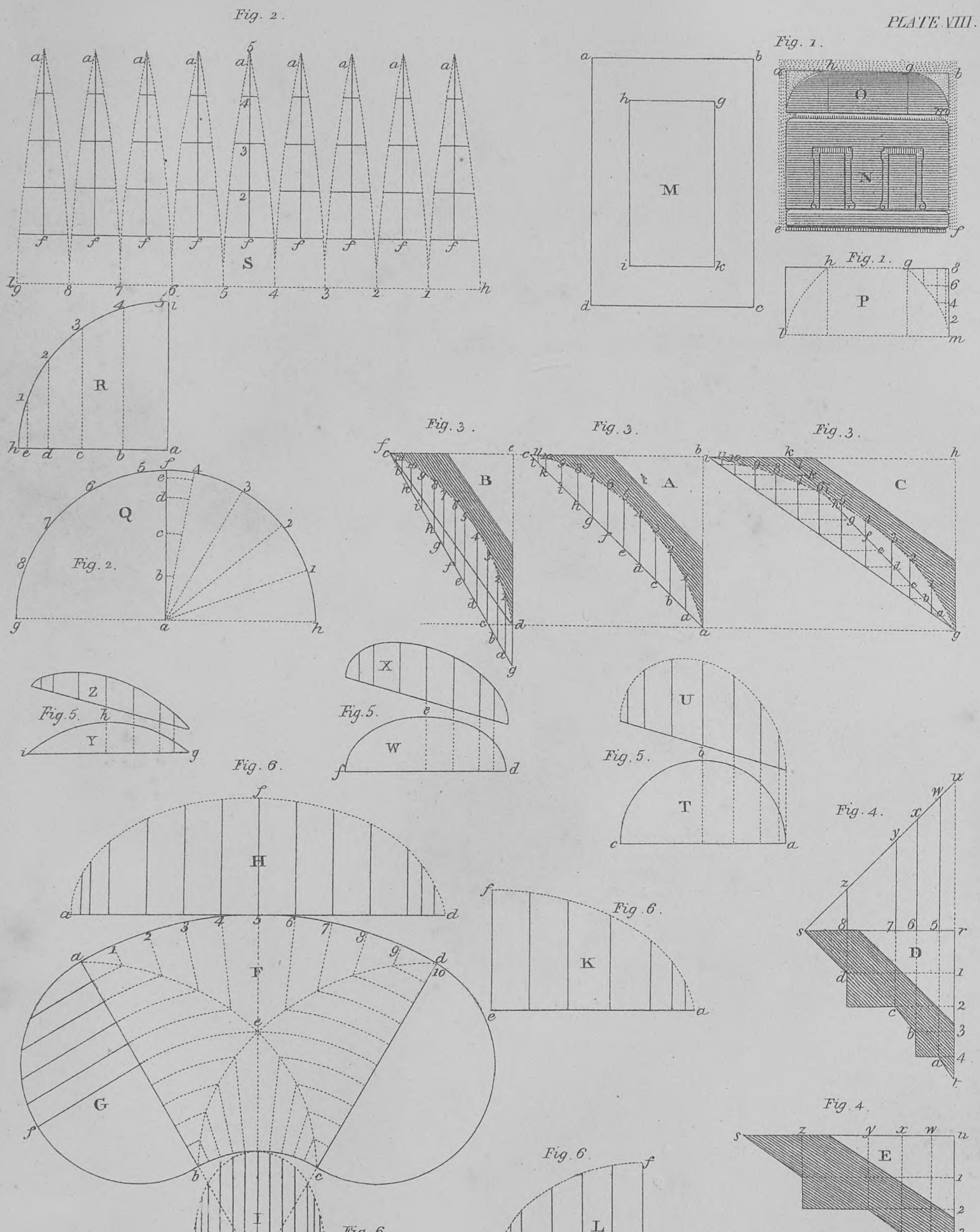
Engd by. R. Thew.

CARPENTRY.

PLATE VIII.

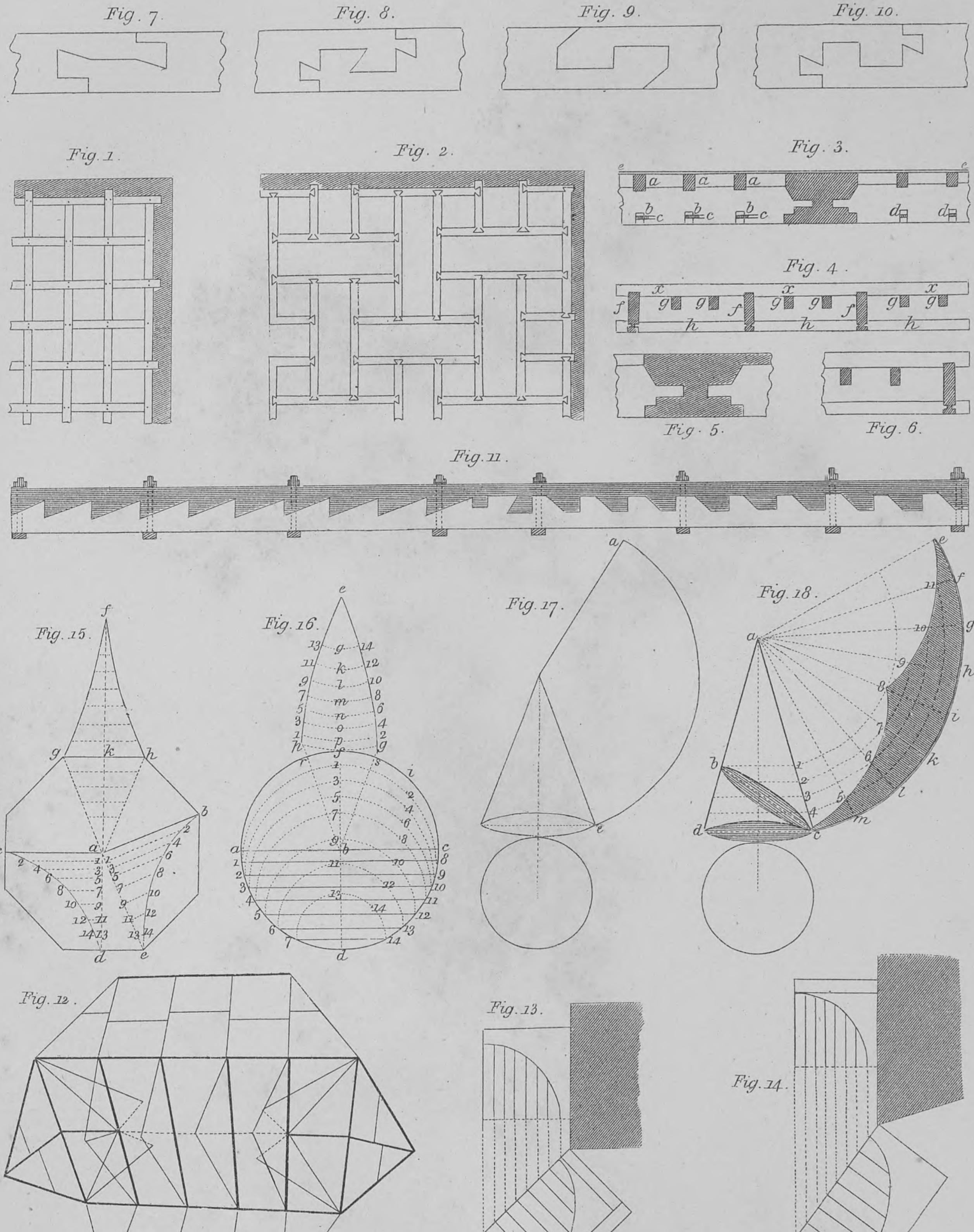


Drawn by P. Nicholson

Eng.d by R. Thew.

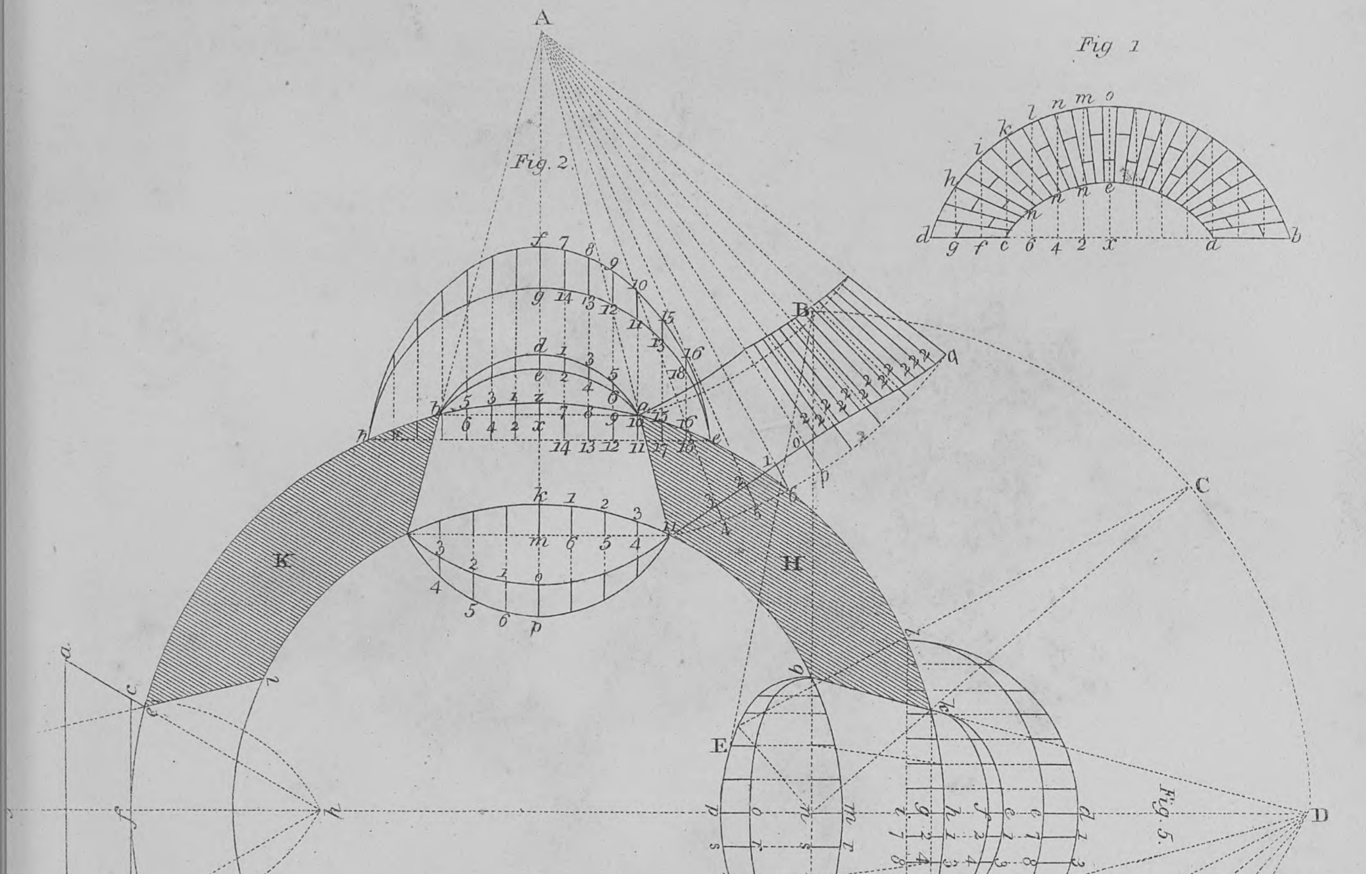
CARPENTRY.

PLATE IX.



Drawn by P Nicholson.

Eng^d by R. Thew.

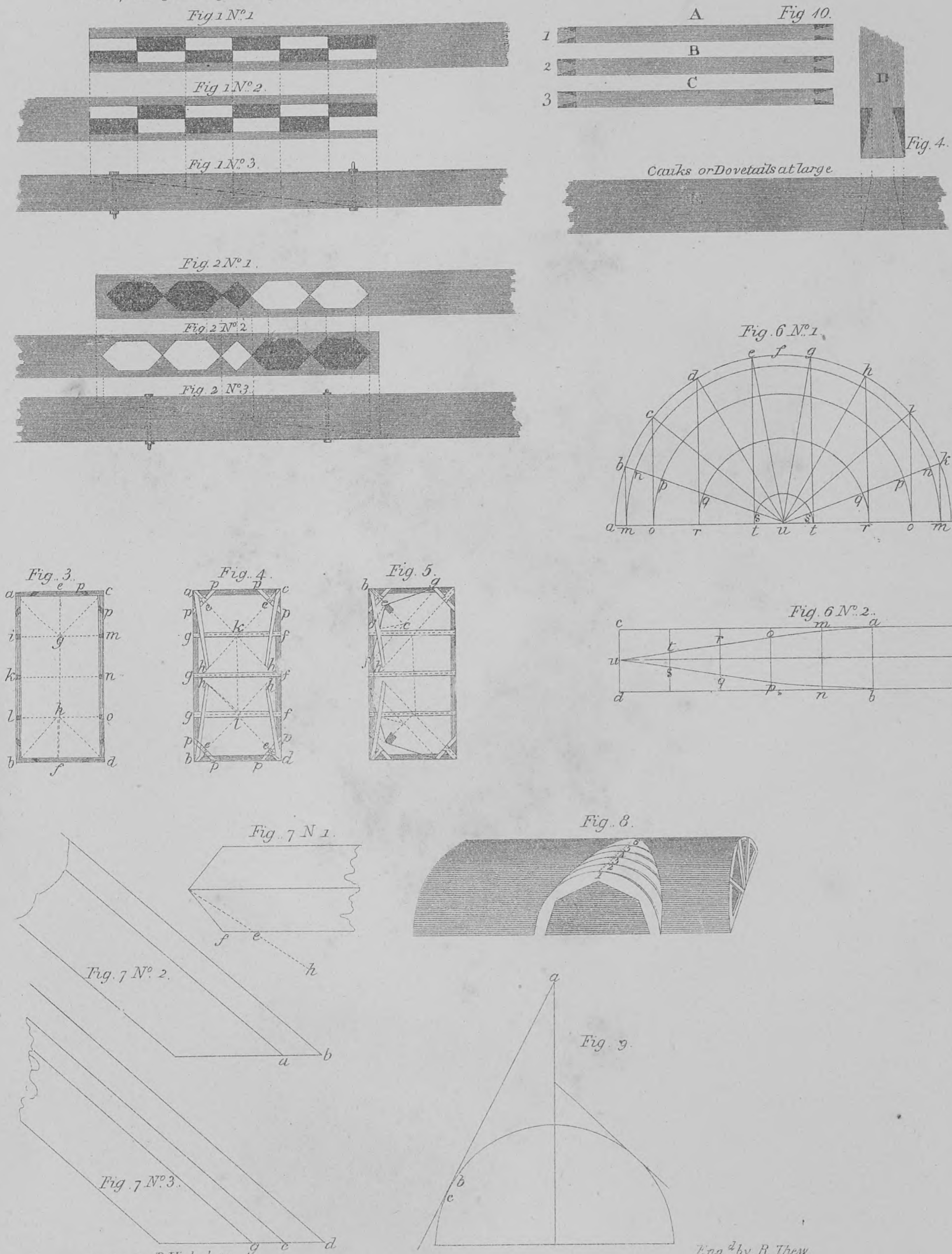


Eng.d by R. Thew.

CARPENTRY

PLATE XI.

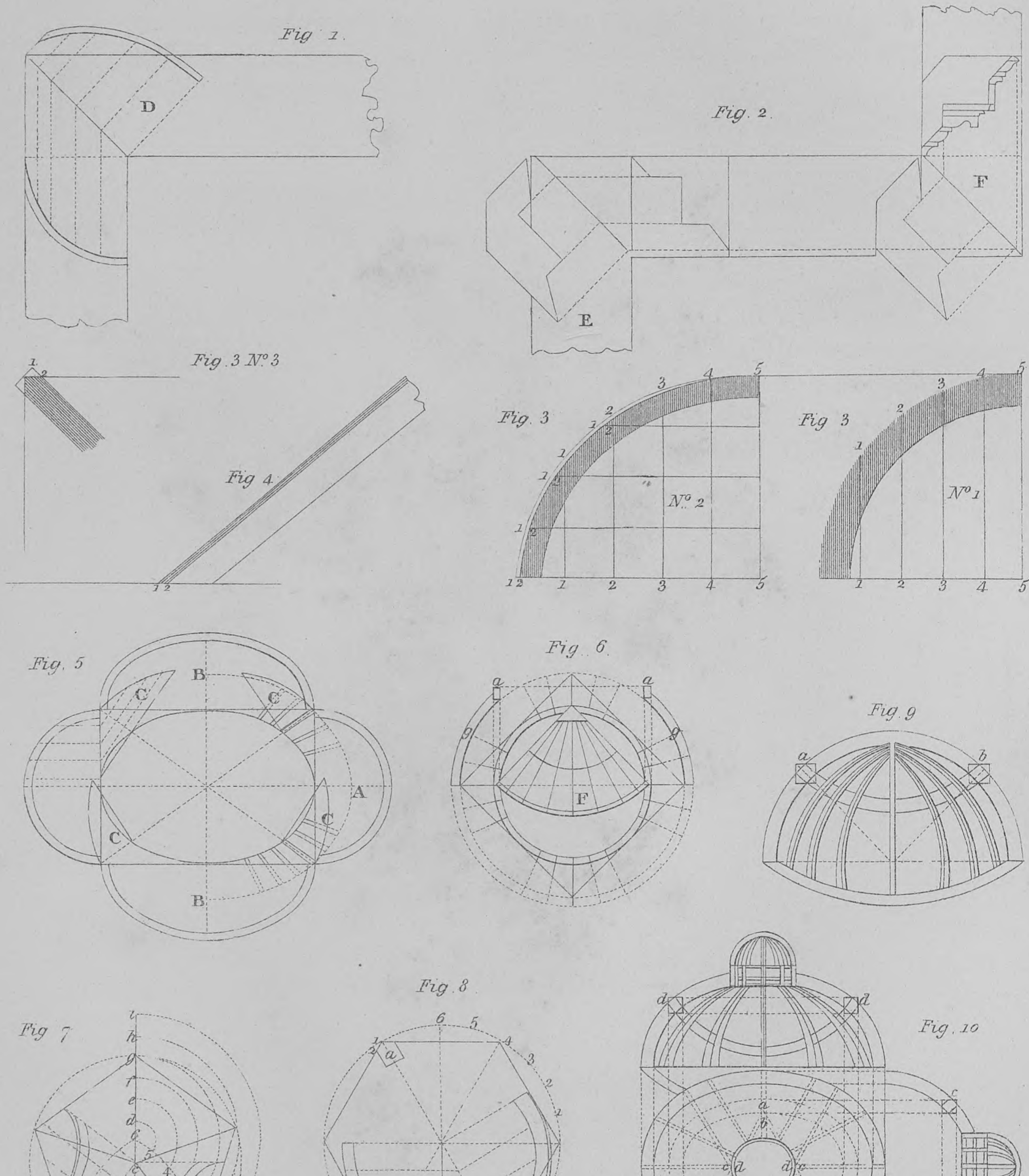
The Splicing or Lengthening of Beams explained.



Drawn by P. Nicholson.

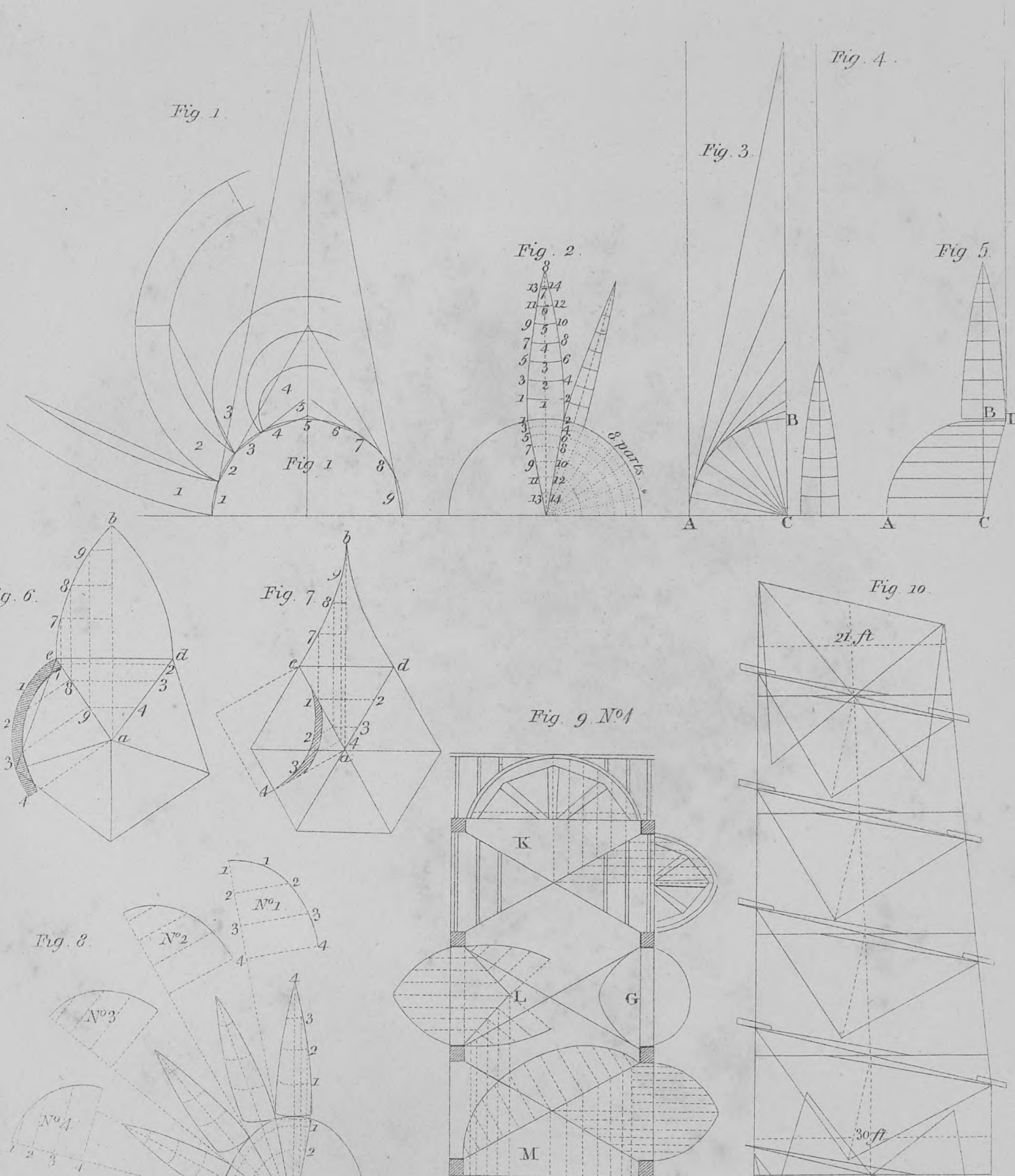
Eng.d by R. Thew.

PLATE XII.



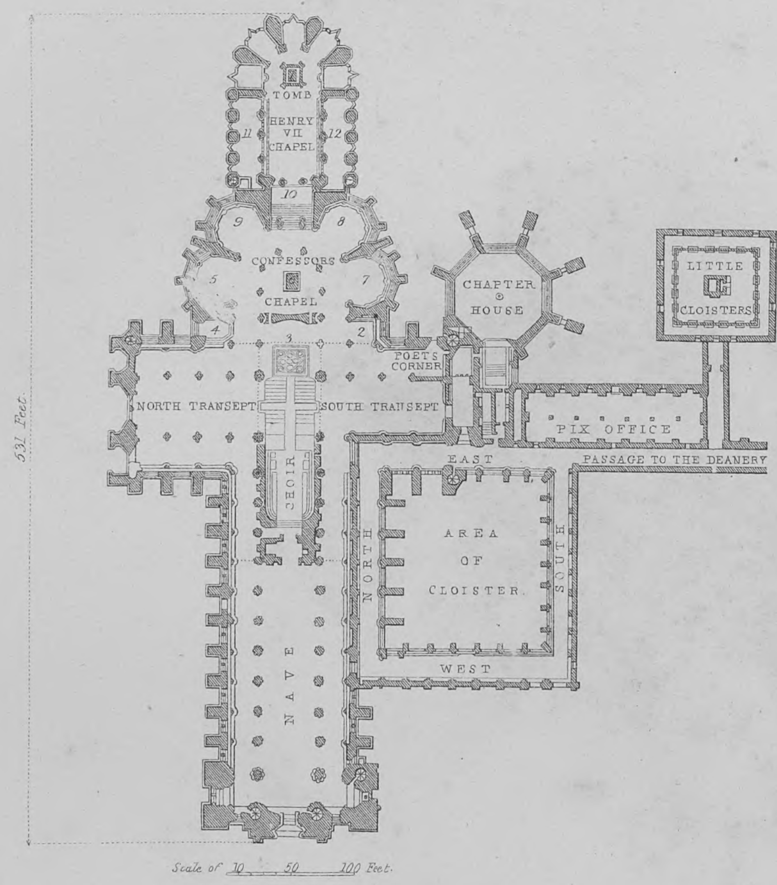
Drawn by P. Nicholson

Eng'd by R. Thew.



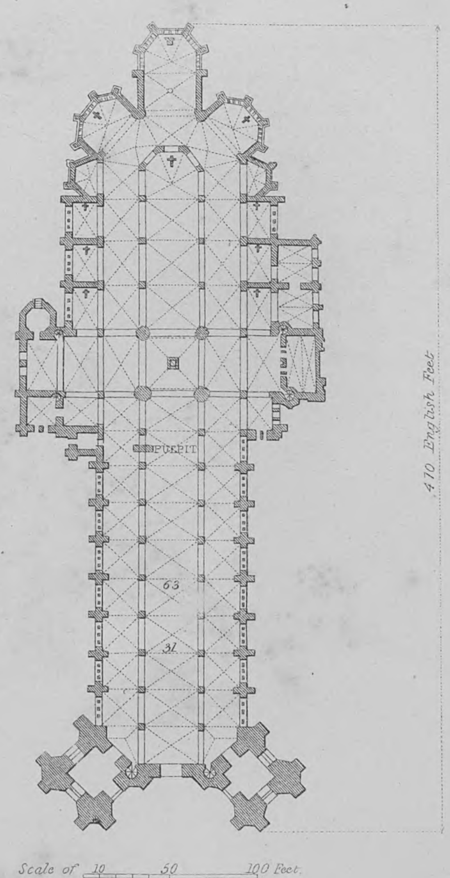
Drawn by P. Nicholson. Eng.d by R. Thew.

PLAN OF AN ENGLISH ABBEY CHURCH.



GENERAL PLAN OF WESTMINSTER ABBEY.

PLAN OF A FRENCH CATHEDRAL CHURCH.



GENERAL PLAN OF ST OUEN AT ROUEN.

R. Brown. Arch.t

R. Thew. sc

CENTERING.

PLATE I.

Fig. 1.

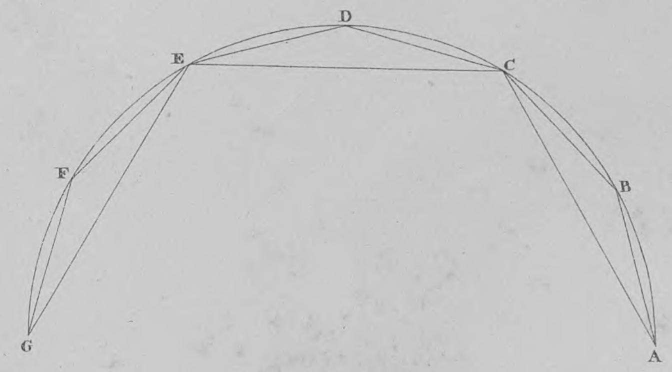


Fig. 2.

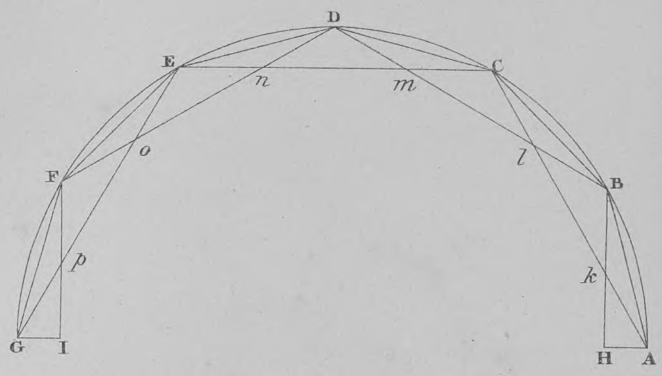


Fig 3

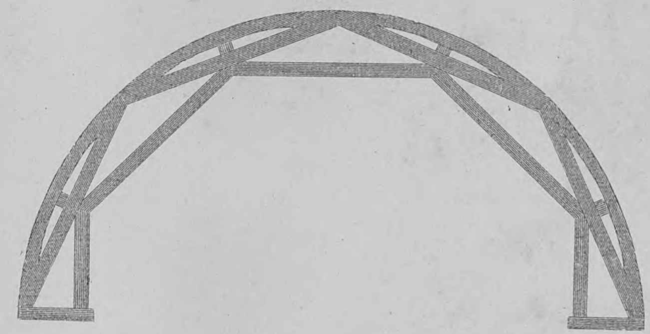


Fig. 4.

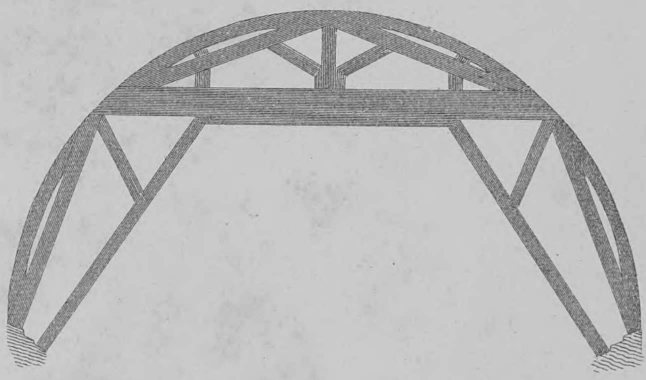


Fig. 5.

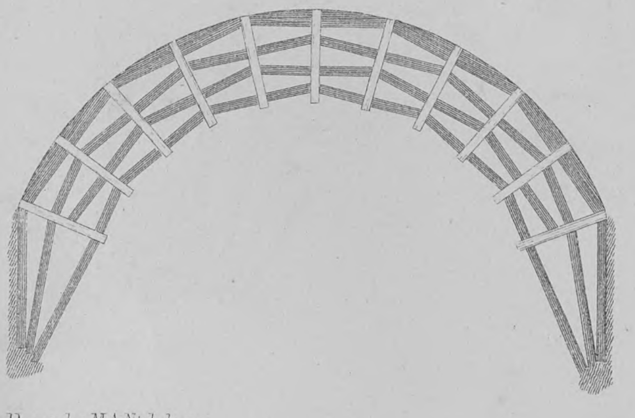


Fig. 6.

Drawn by M.A. Nicholson. Engd by R. Thew.

CENTRE, PLATE 2.

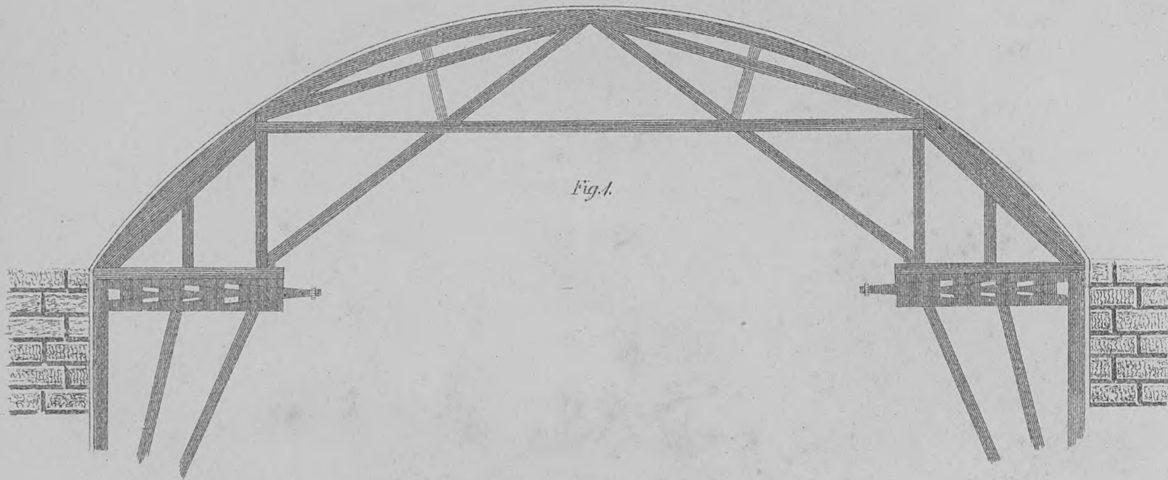


Fig.1.

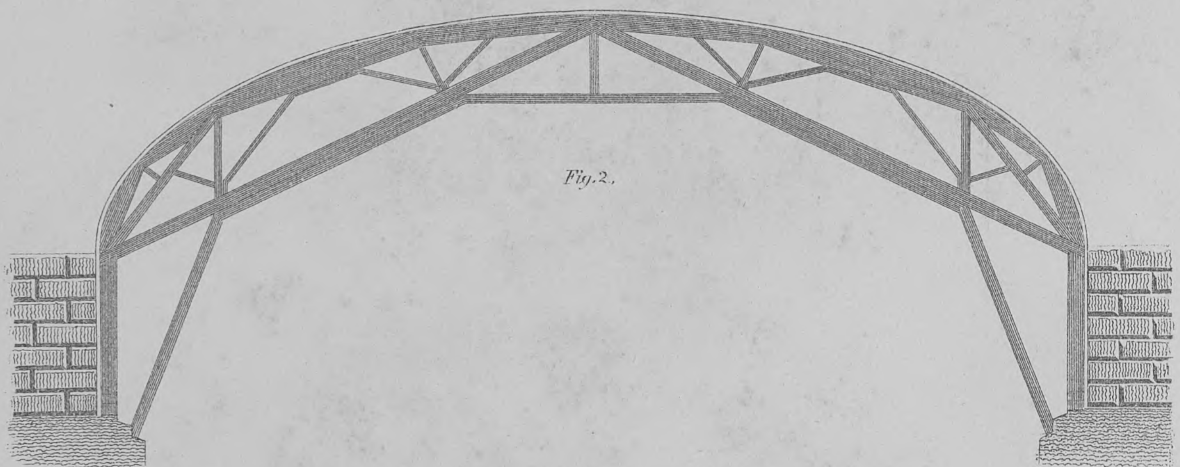


Fig.2.

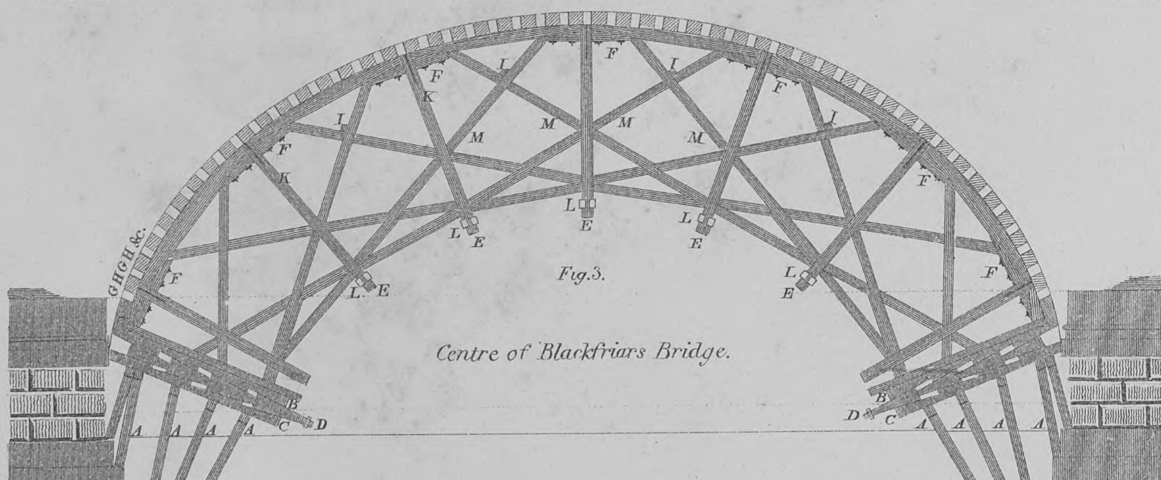


Fig.3.

Centre of Blackfriars Bridge.

Drawn by M. A. Nicholson.

Eng.d by R. Thew.

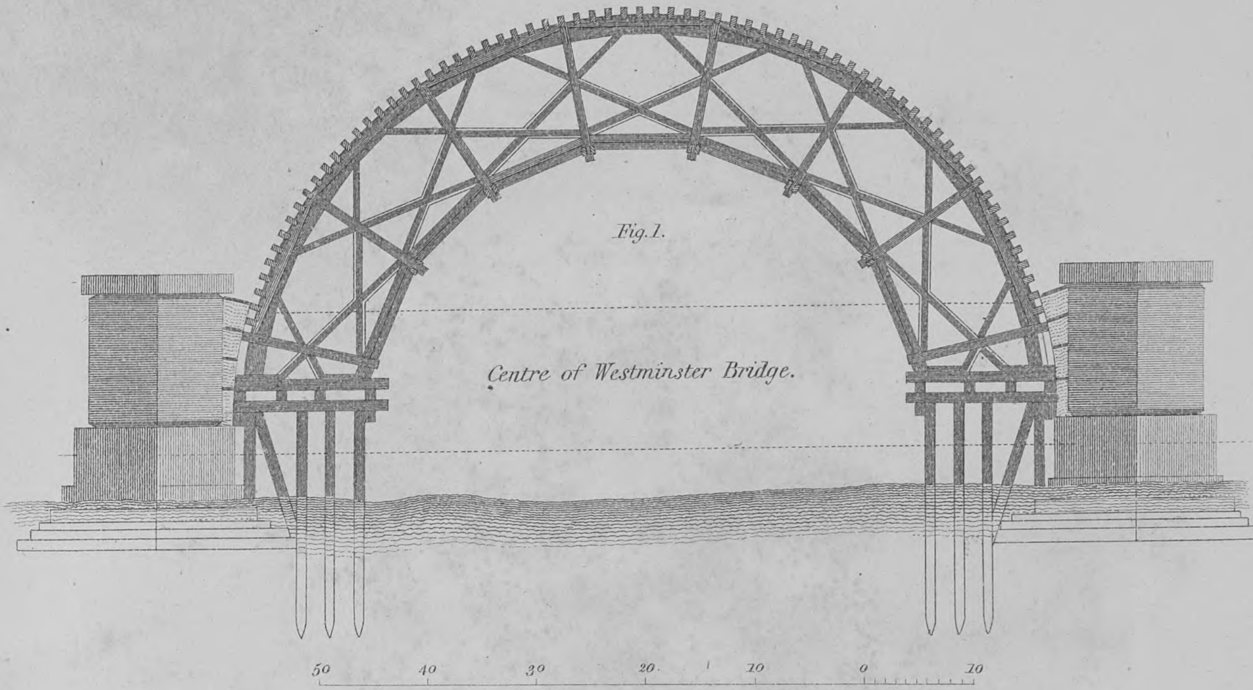


Fig. 1.

Centre of Westminster Bridge.

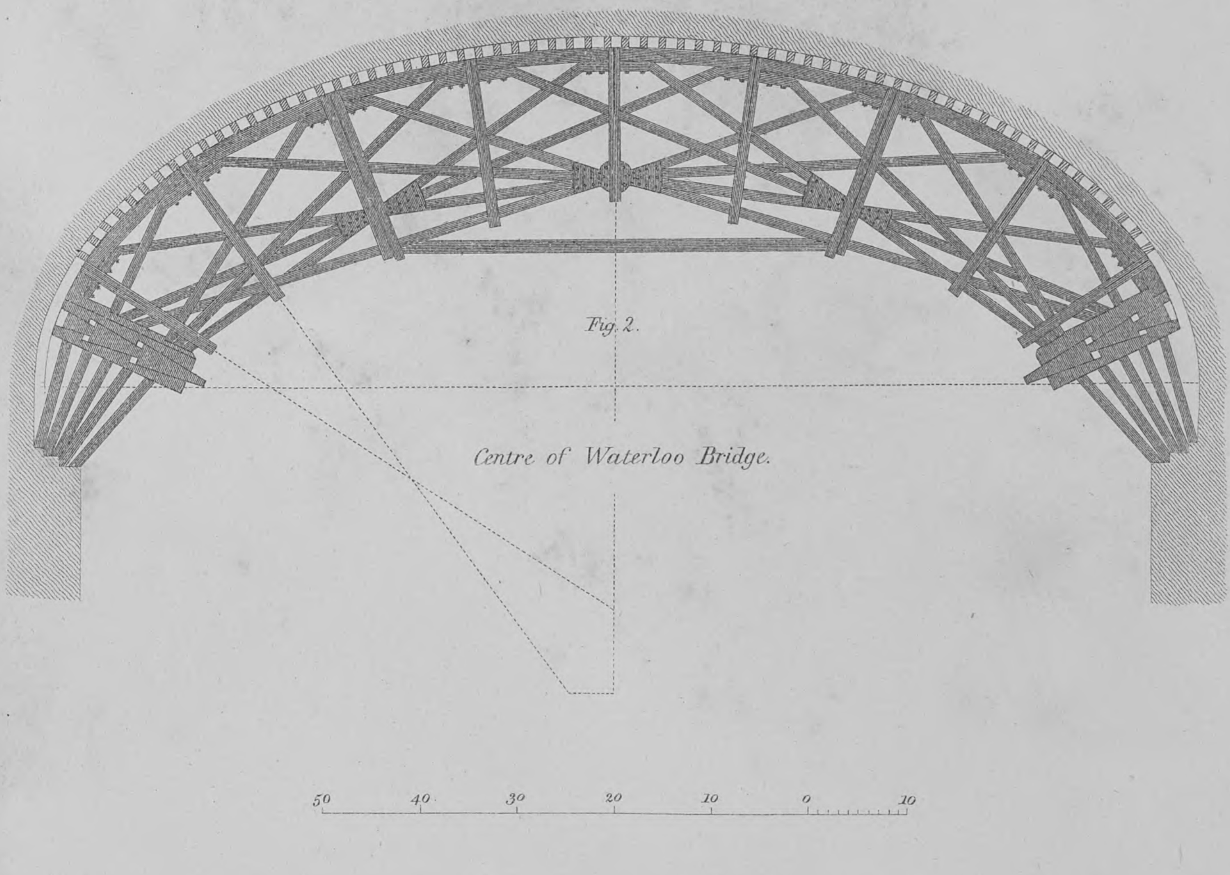
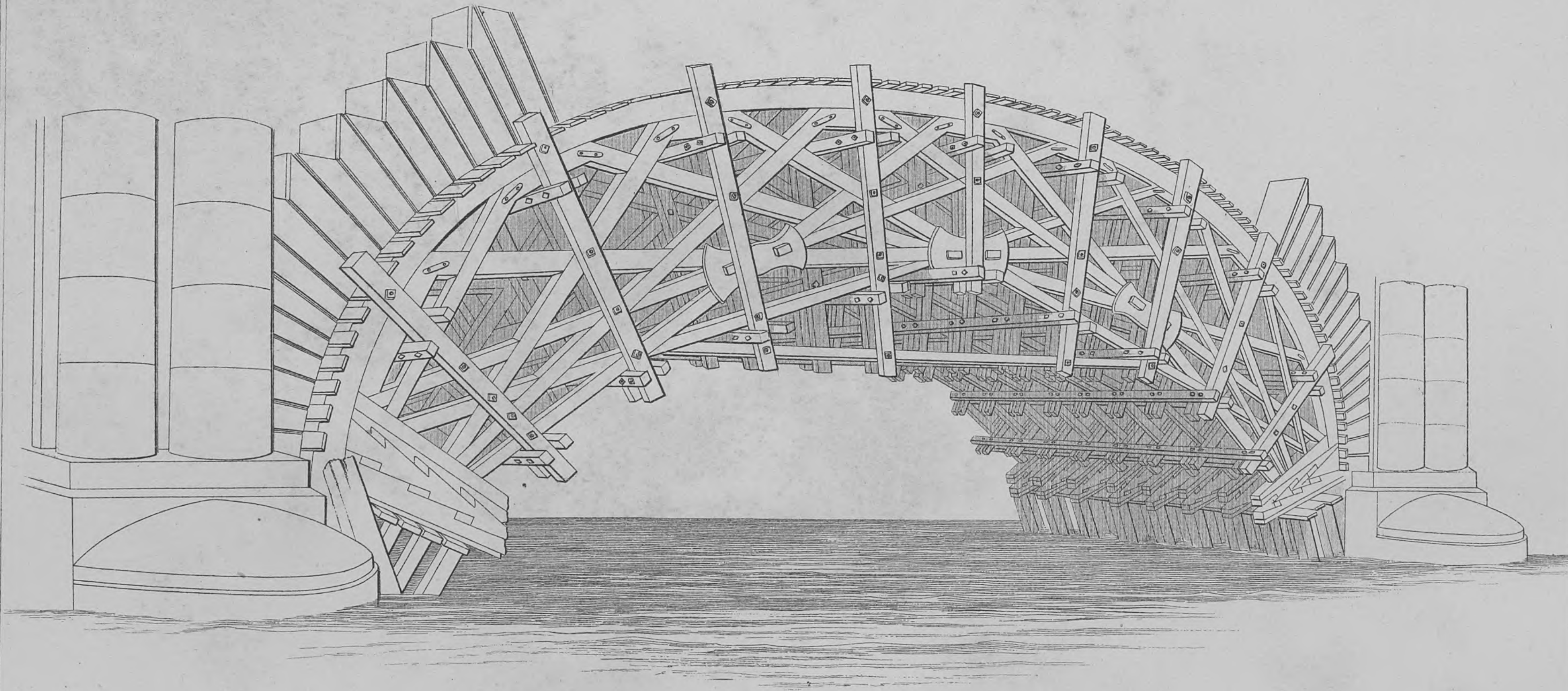


Fig. 2.

Centre of Waterloo Bridge.

Drawn by P. Nicholson. Eng^d by R. Thew.

CENTRE OF WATERLOO BRIDGE.



A. Gilbert del.

R. Thew sc.

Fig. 3.

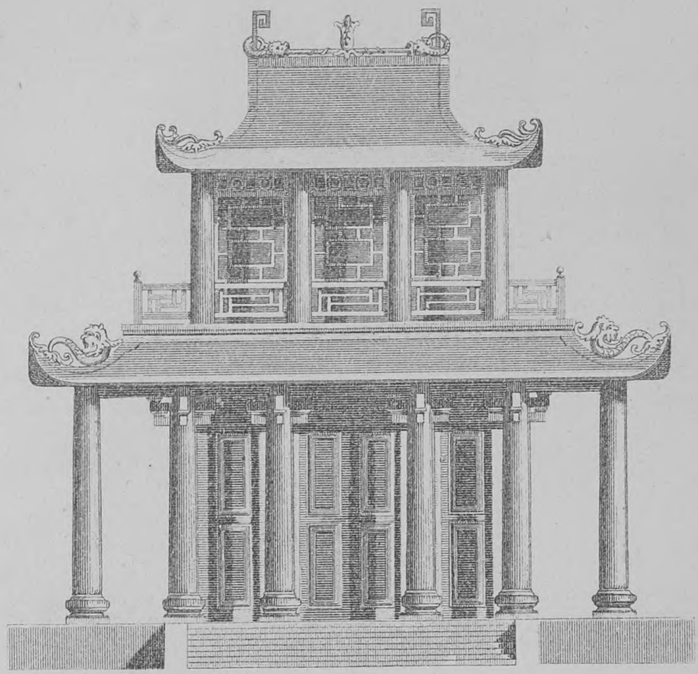
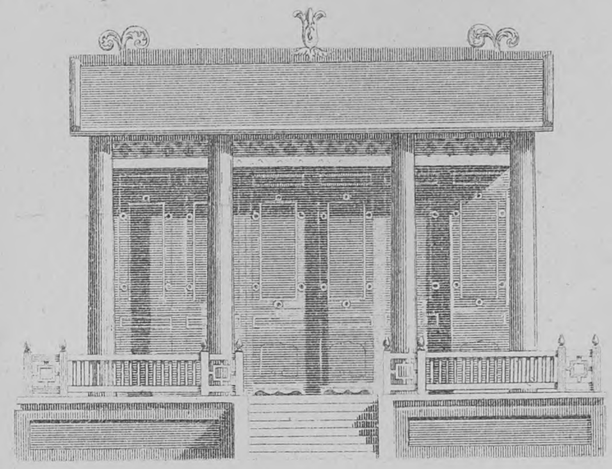


Fig. 2.



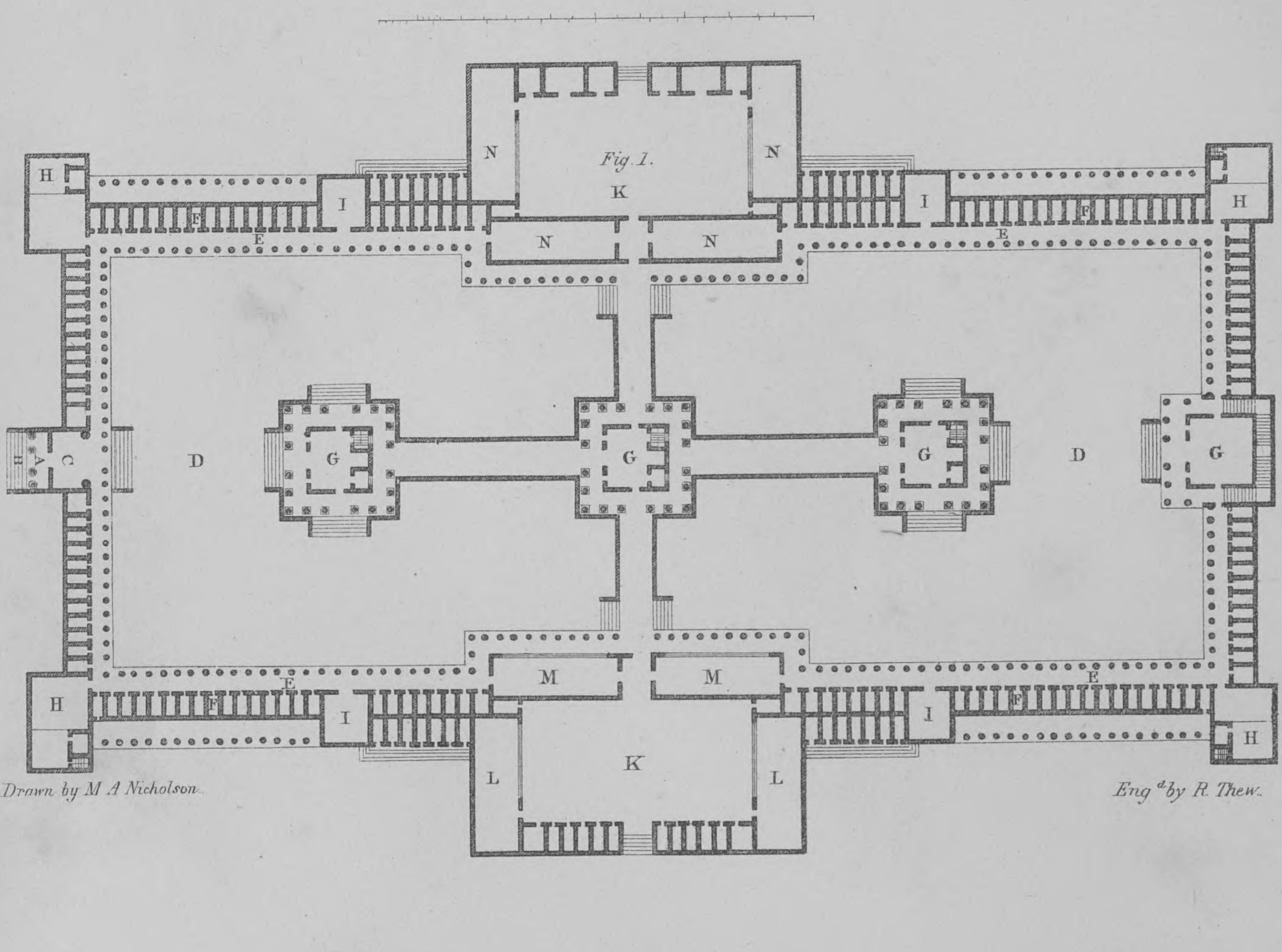
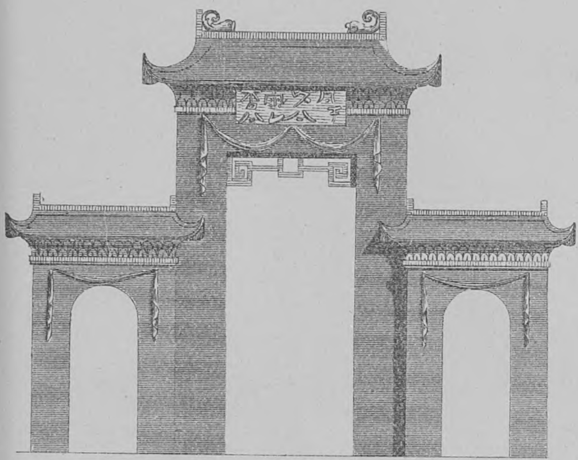


Fig. 1.

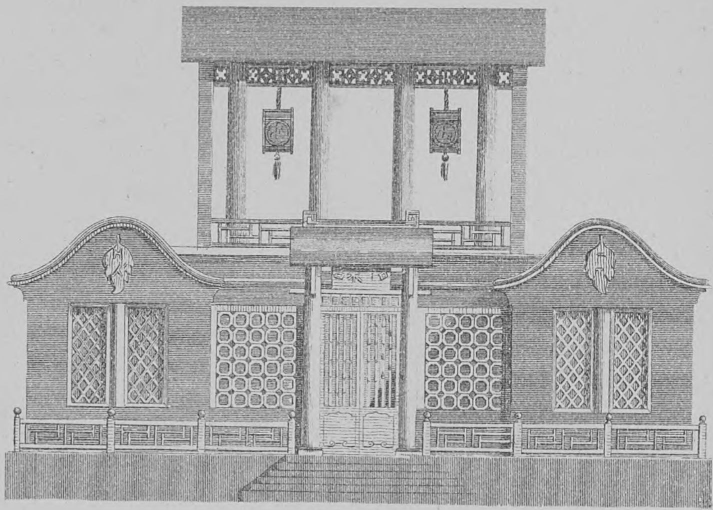
Drawn by M A Nicholson. Engd by R. Thew.

Fig. 1.



TRIUMPHAE ARCH

Fig. 2.



HOUSE OR SHOP

Fig. 4.

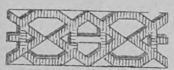


Fig. 5.

Fig. 6.

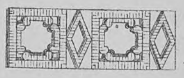


Fig 7

Fig. 3.

BRIDGE
AT CANTON

Drawn by. M. A. Nicholson

Eng^d by. R. Thew.

CHINESE ARCHITECTURE.

PLATE III.

Fig. 1.

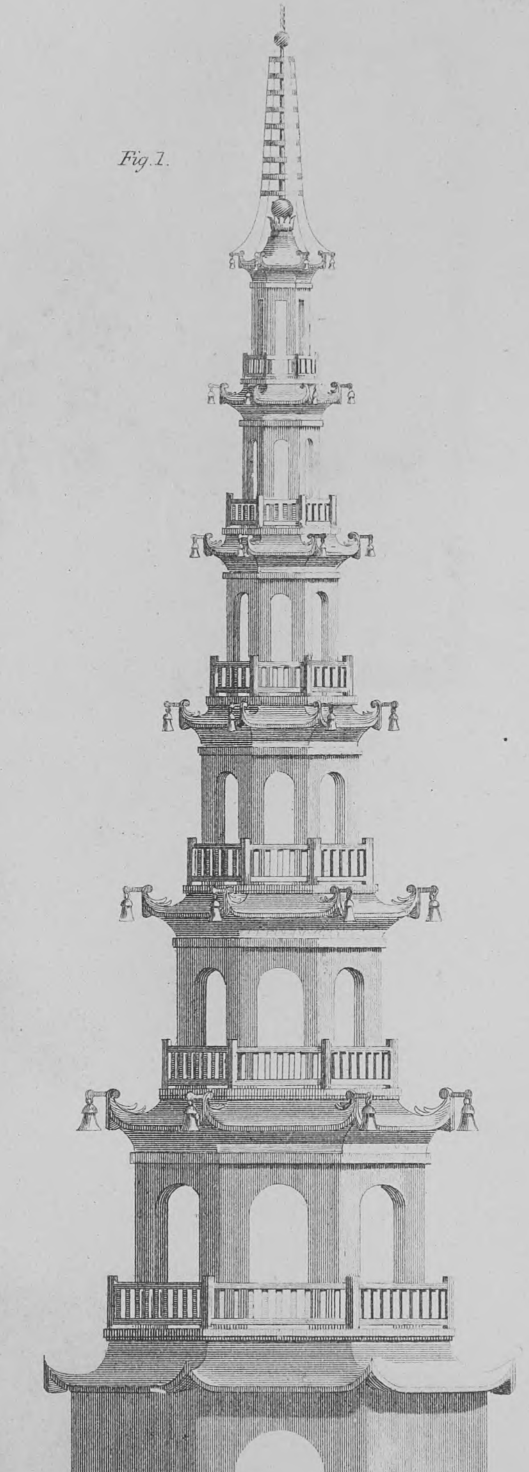


Fig. 2.

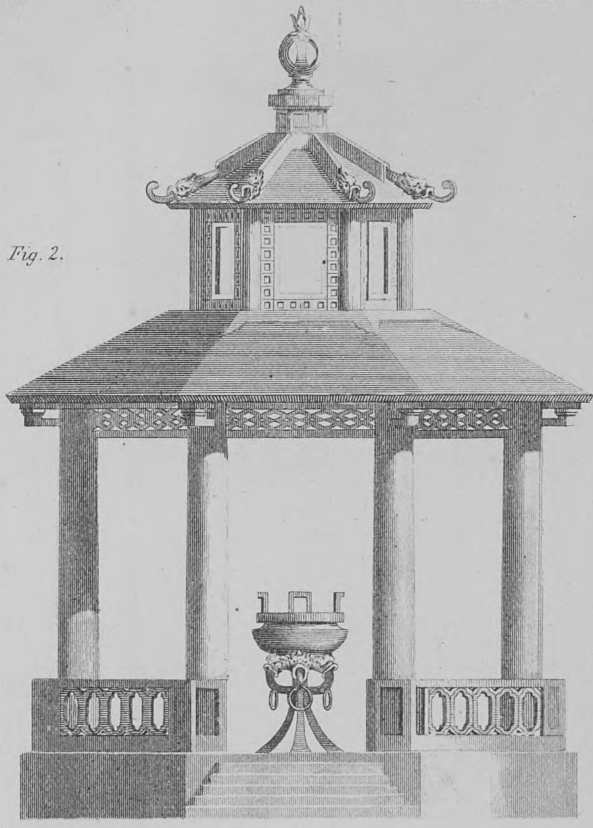


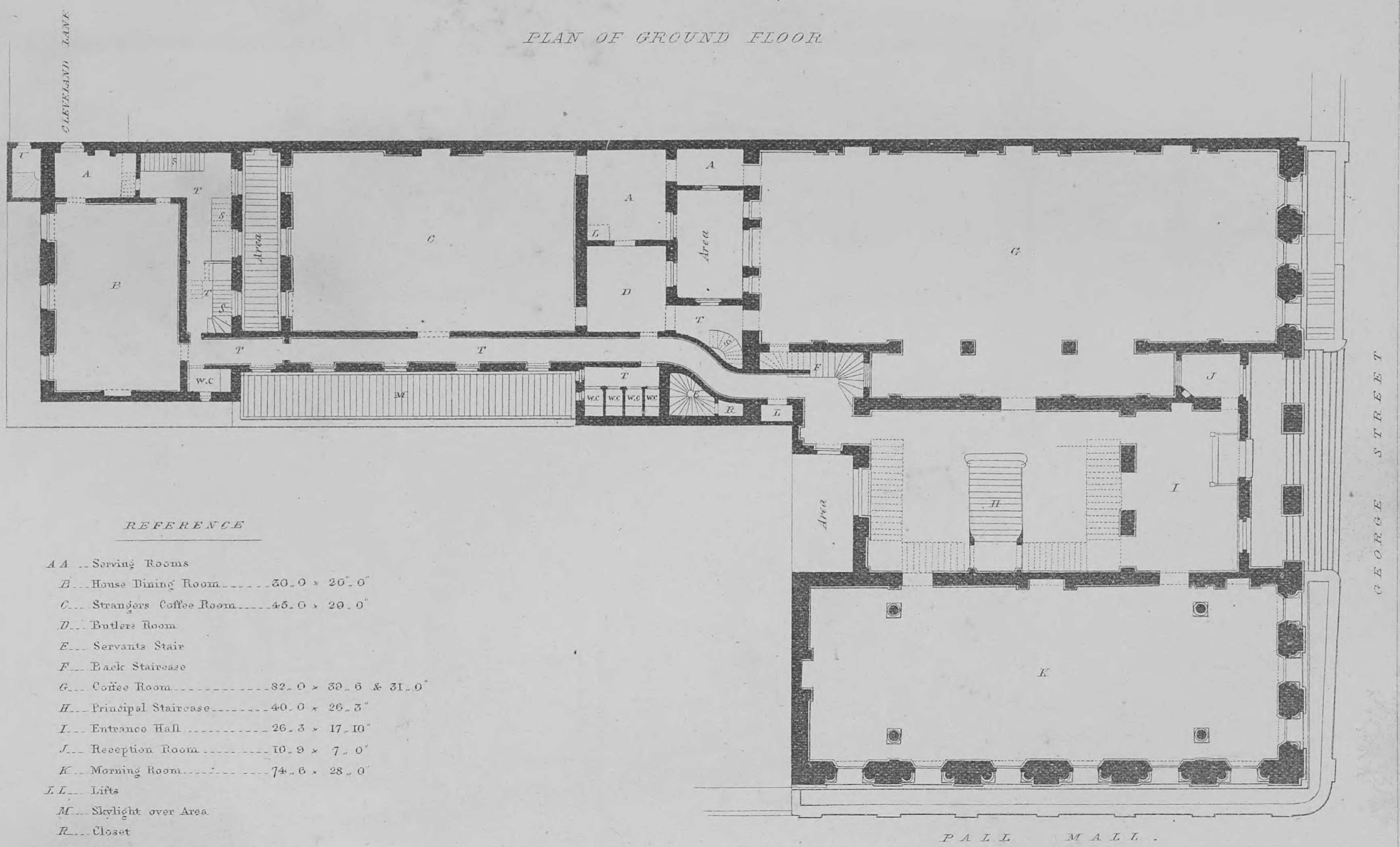
Fig. 3.

Drawn by M. A. Nicholson.

Eng.d by R. Thew

ARMY & NAVY CLUB HOUSE,

PLAN OF GROUND FLOOR



REFERENCE

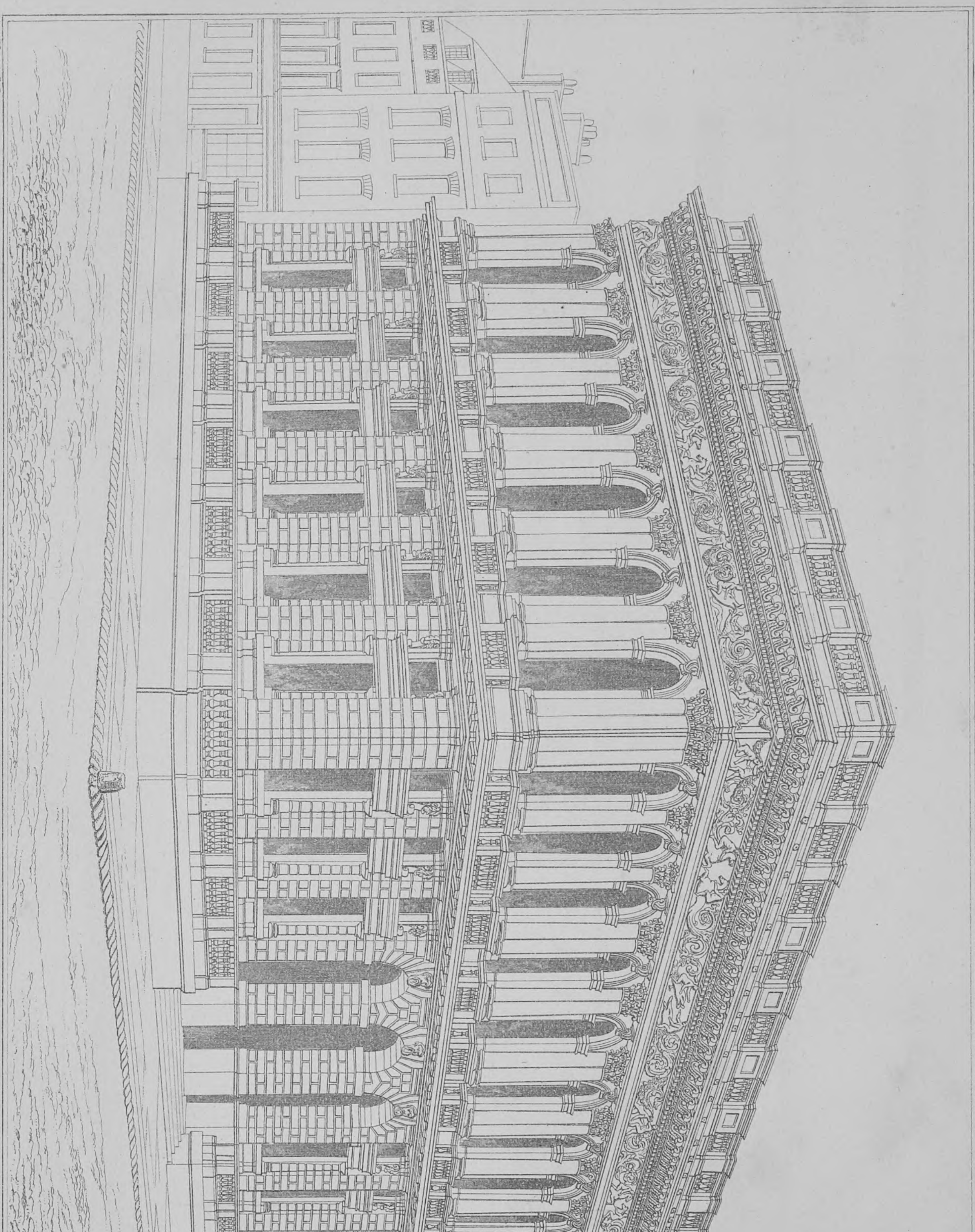
A A ... Serving Rooms
B ... House Dining Room .... 30 . 0 × 20 . 0"
C ... Strangers Coffee Room ...... 45 . 0 × 29 . 0"
D ... Butlers Room
E ... Servants Stair
F ... Back Staircase
G ... Coffee Room .... 82 . 0 × 39 . 6 & 31 . 0"
H ... Principal Staircase .... 40 . 0 × 26 . 3"
I ... Entrance Hall .... 26 . 3 × 17 . 10"
J ... Reception Room .... 10 . 9 × 7 . 0"
K ... Morning Room .... 74 . 6 × 28 . 0"
L L ... Lifts
M ... Skylight over Area.
R ... Closet
S.S ... Stairs
T.T ... Corridors.
W.C ... Water Closets
V ... Entrance to Kitchen depart! from Lane.

10 5 0 10 20 30 40 50 60 70 80 90 100 feet.

Mefs.rs Parnell & Smith, Arch.ts

R. Thew. sc.

A. Gilbert del.

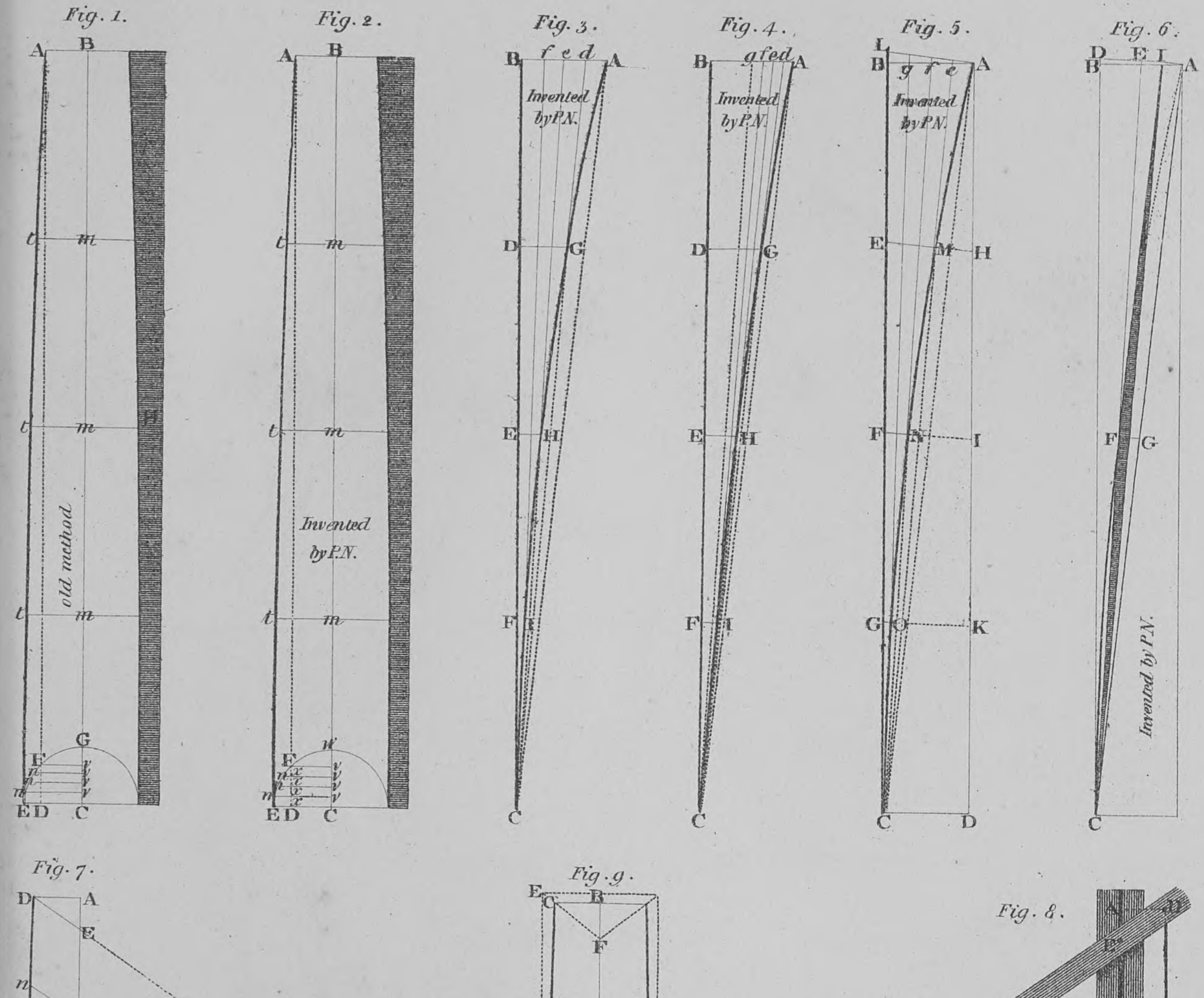


H. Thew sc.

ARMY AND NAVY CLUB HOUSE, LONDON.

COLUMN.

PLATE I.



Drawn by P. Nicholson.

Eng.d by R. Thew.

Fig. 1.

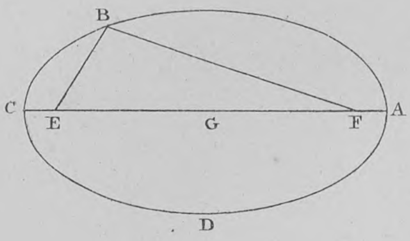


Fig. 2.

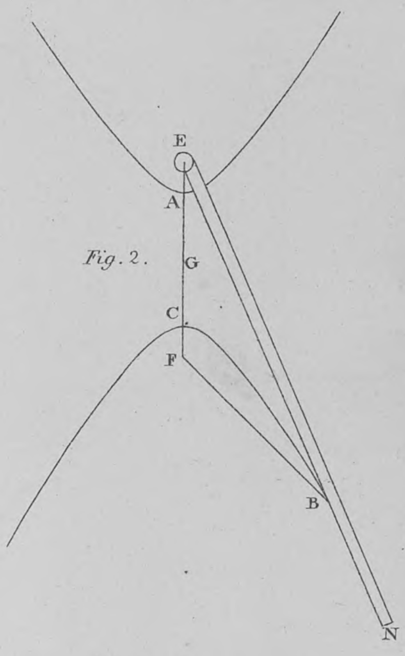


Fig. 3.

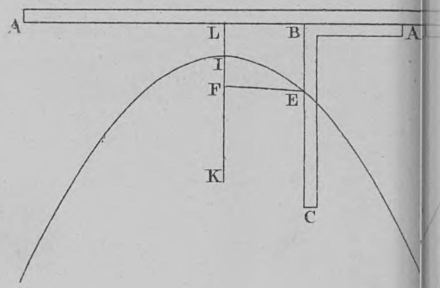


Fig. 6.

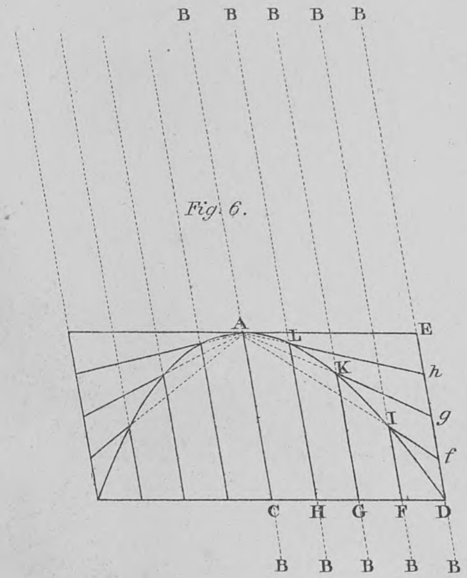


Fig. 5.

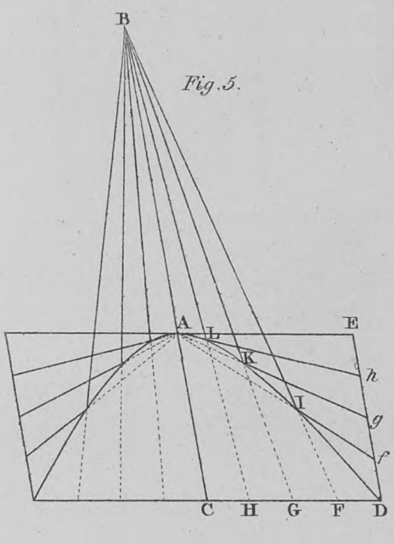
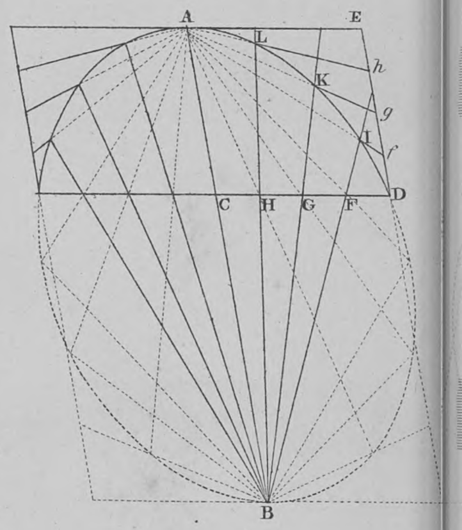


Fig. 4.



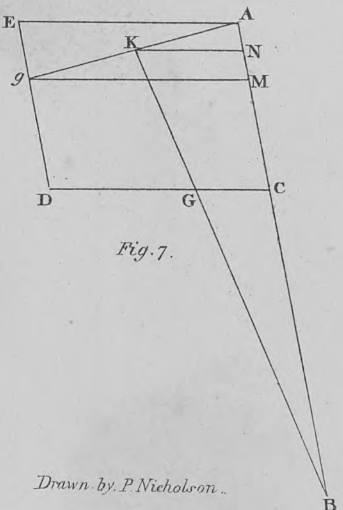


Fig. 7.

Fig. 8.

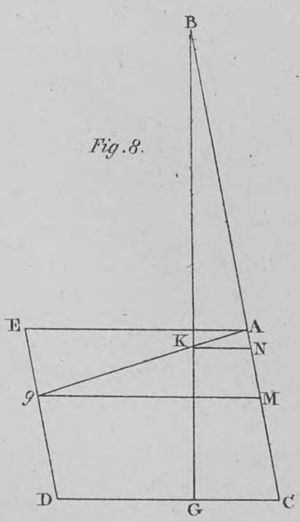
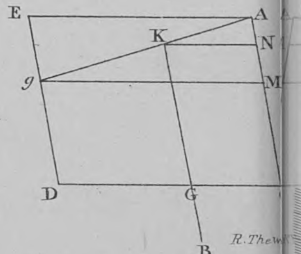


Fig. 9.



Drawn by P. Nicholson.

R. Thew

CONSTRUCTIVE CARPENTRY.

PLATE I.

Fig 1

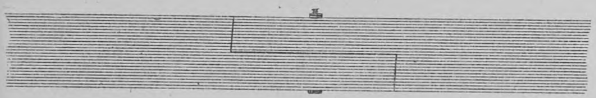


Fig. 2

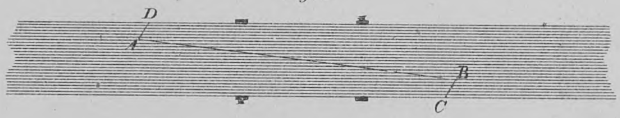


Fig. 3

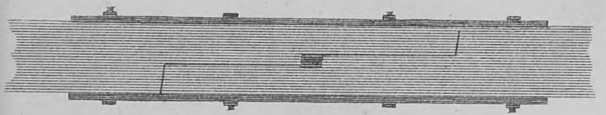


Fig. 4.

Fig. 5.

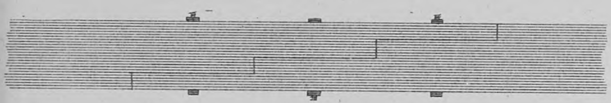


Fig. 6.

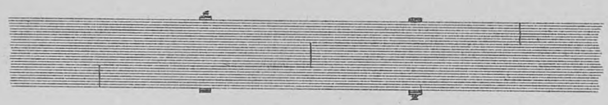


Fig. 7.

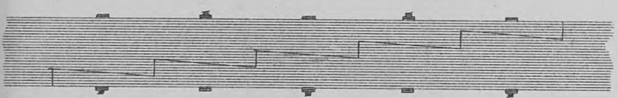


Fig. 8.

Fig. 9.

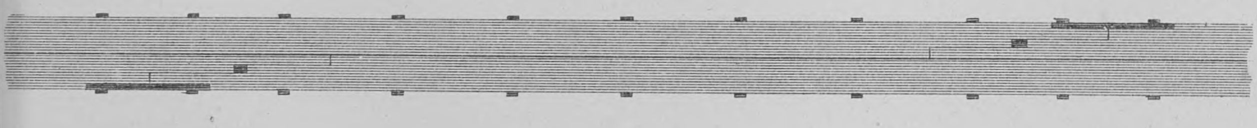


Fig 10.

...own by M.A Nicholson. Eng[d] by R. Thew.

Fig. 11.

Fig. 12. No. 1.

Fig. 12. No. 2.

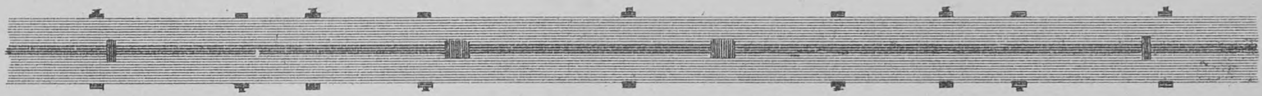


Fig 11. No. 3.

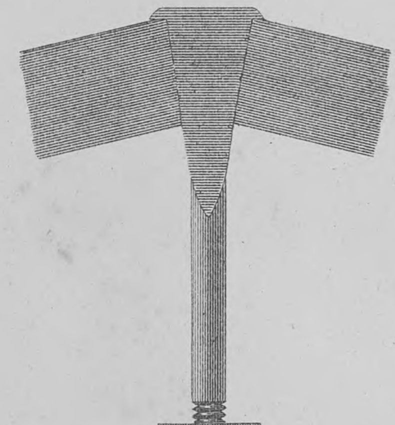


Fig 12. No. 4.

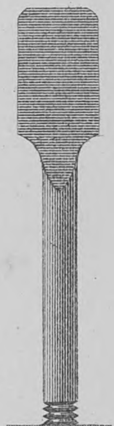


Fig 11. & 12. No. 5.

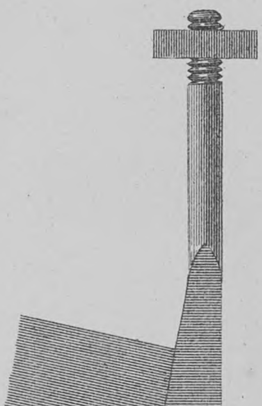


Fig 11. & 12. No. 6.

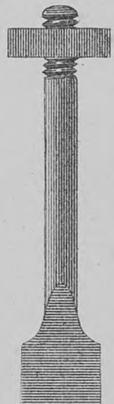


Fig 12 No. 7

Fig 13 No. 1.

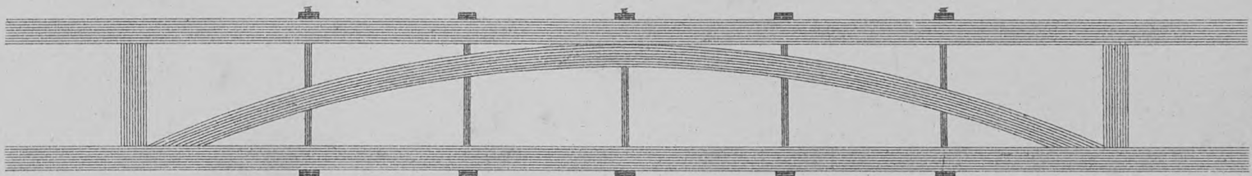
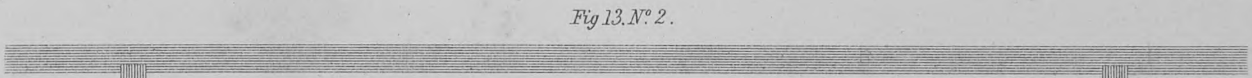


Fig 13. No. 2.



Drawn by M.A. Nicholson

Engd by R. Thew

CORINTHIAN ORDER, PLATE 1.

Fig. 2
No. 2.

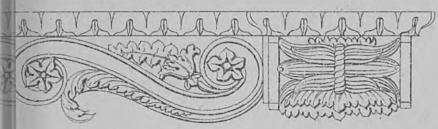


Fig. 2.
No. 1.

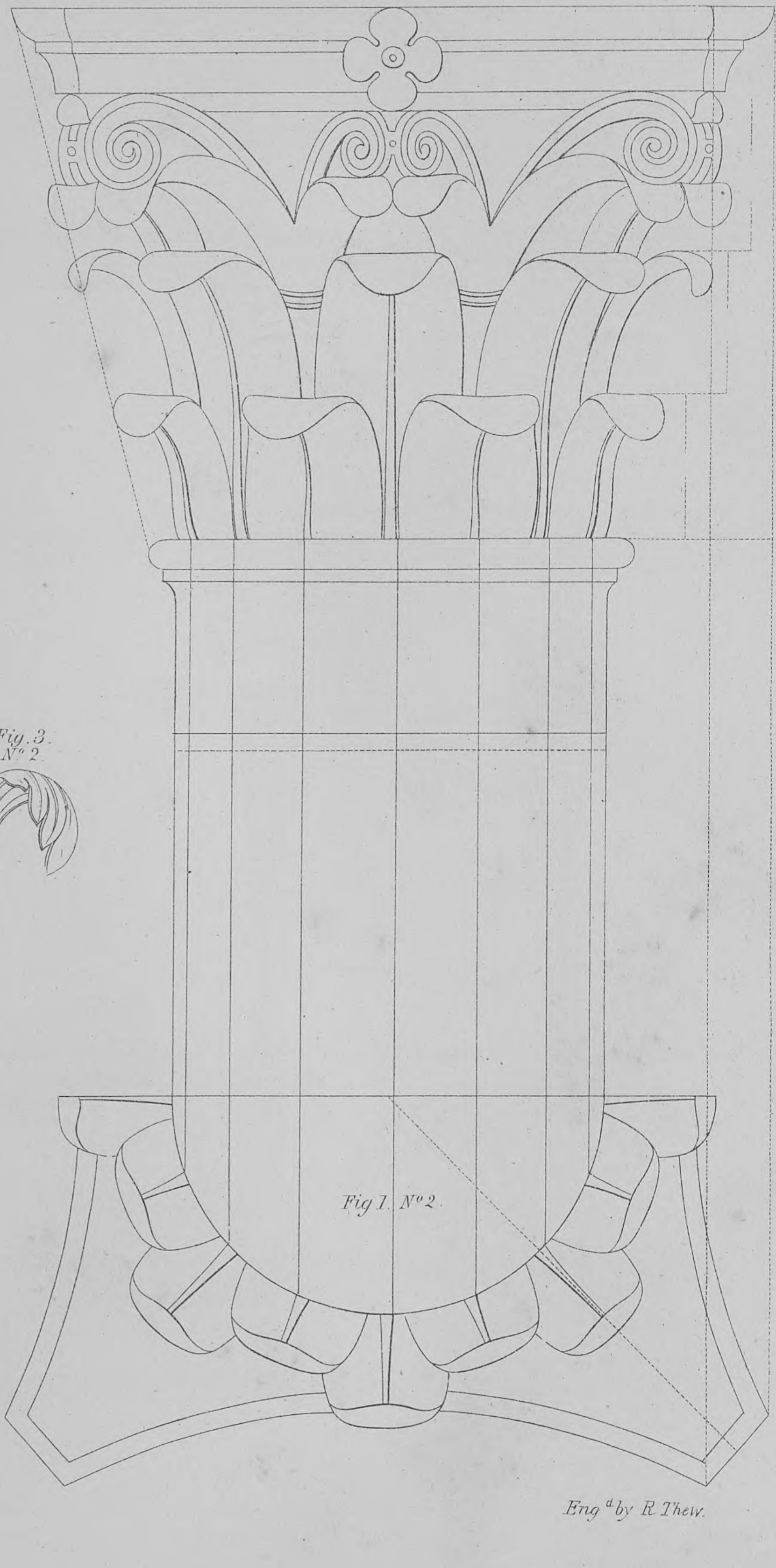


Fig. 2.

No. 1.

Fig. 3
No. 1.

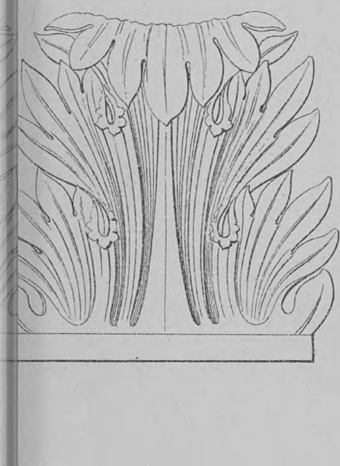


Fig. 3
No. 2.

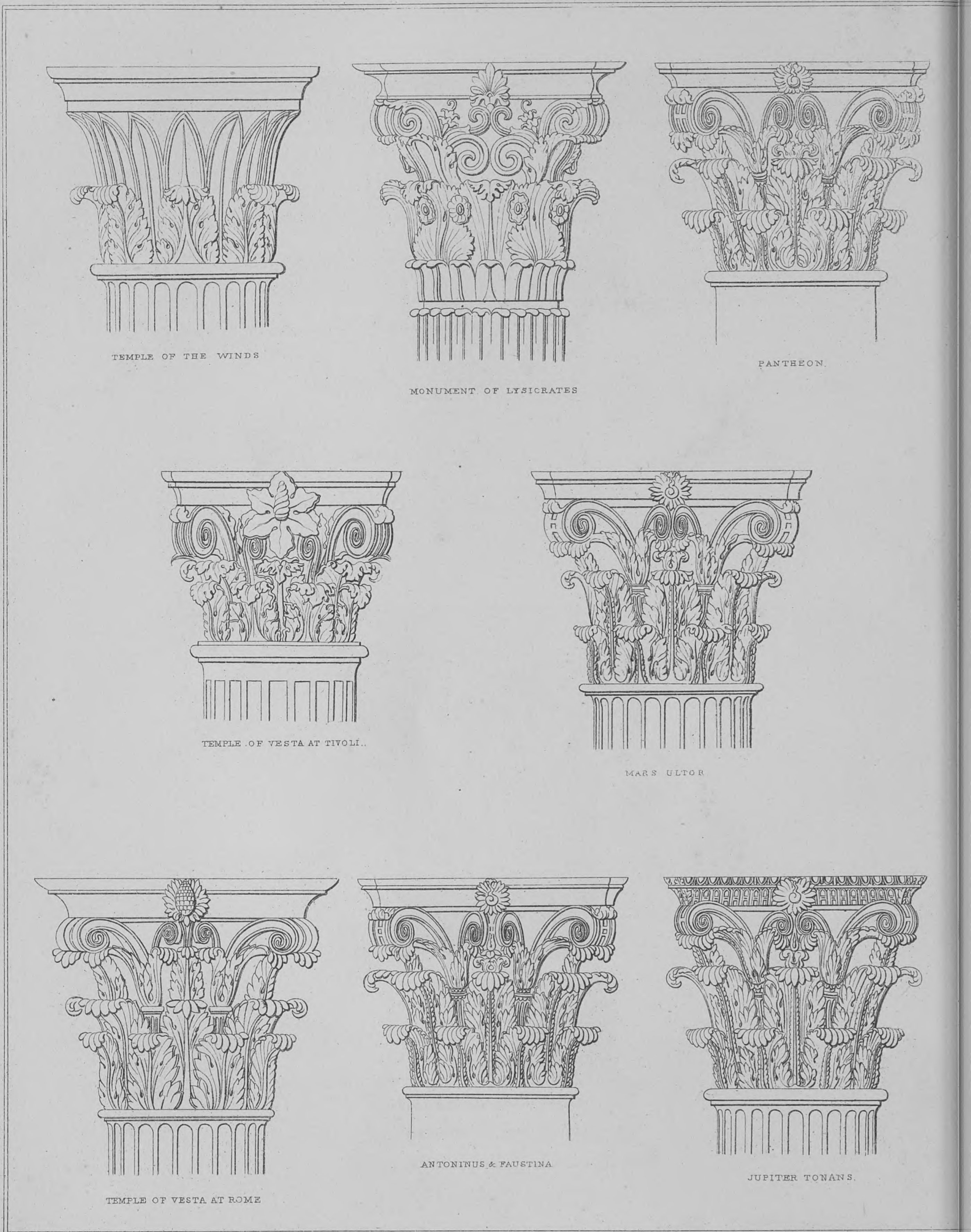
Fig. 1. No. 2.

Fig. 4

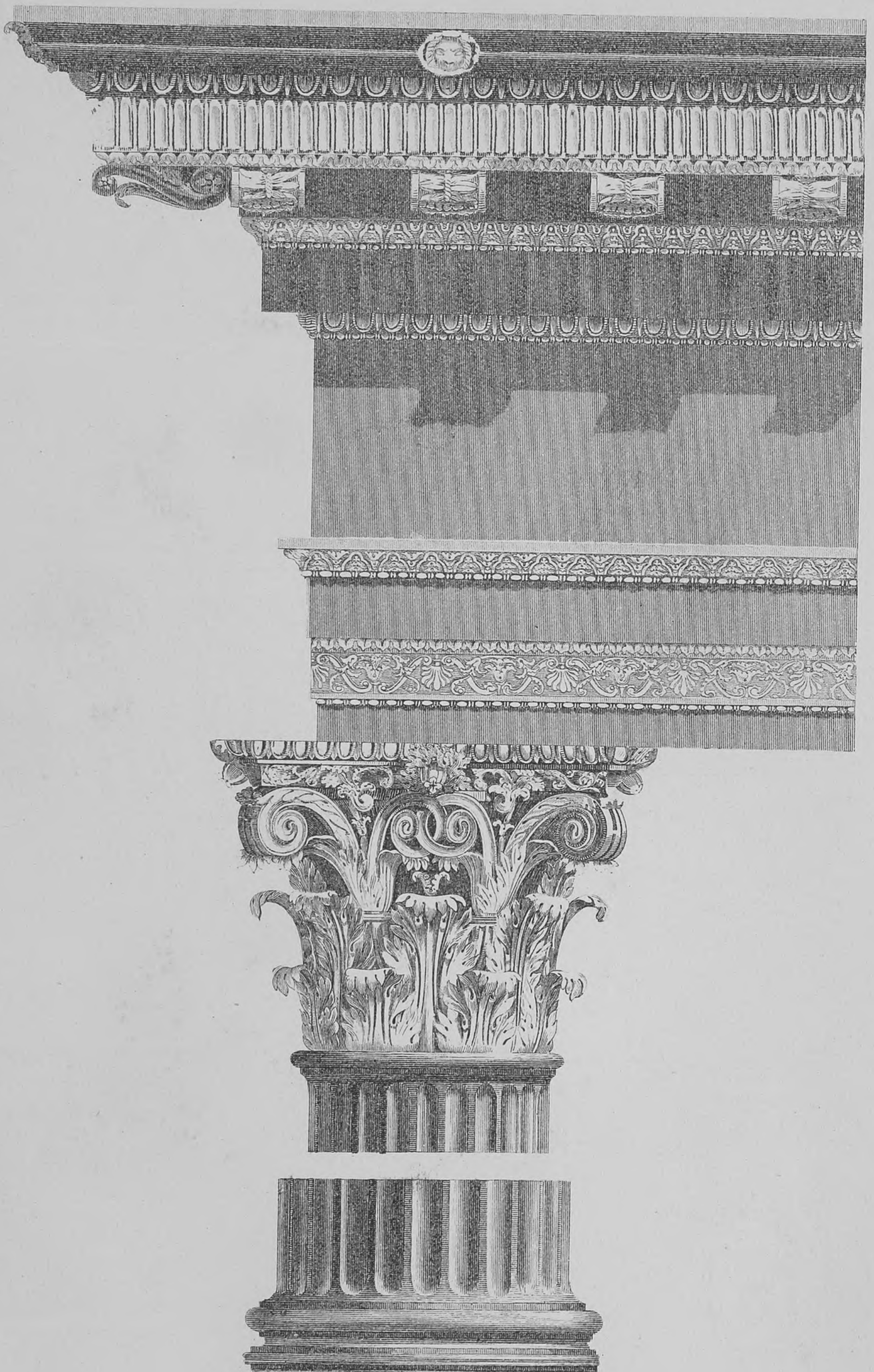
Drawn by P. Nicholson

Eng^{d} by R. Thew.

CORINTHIAN ORDER PLATE II.

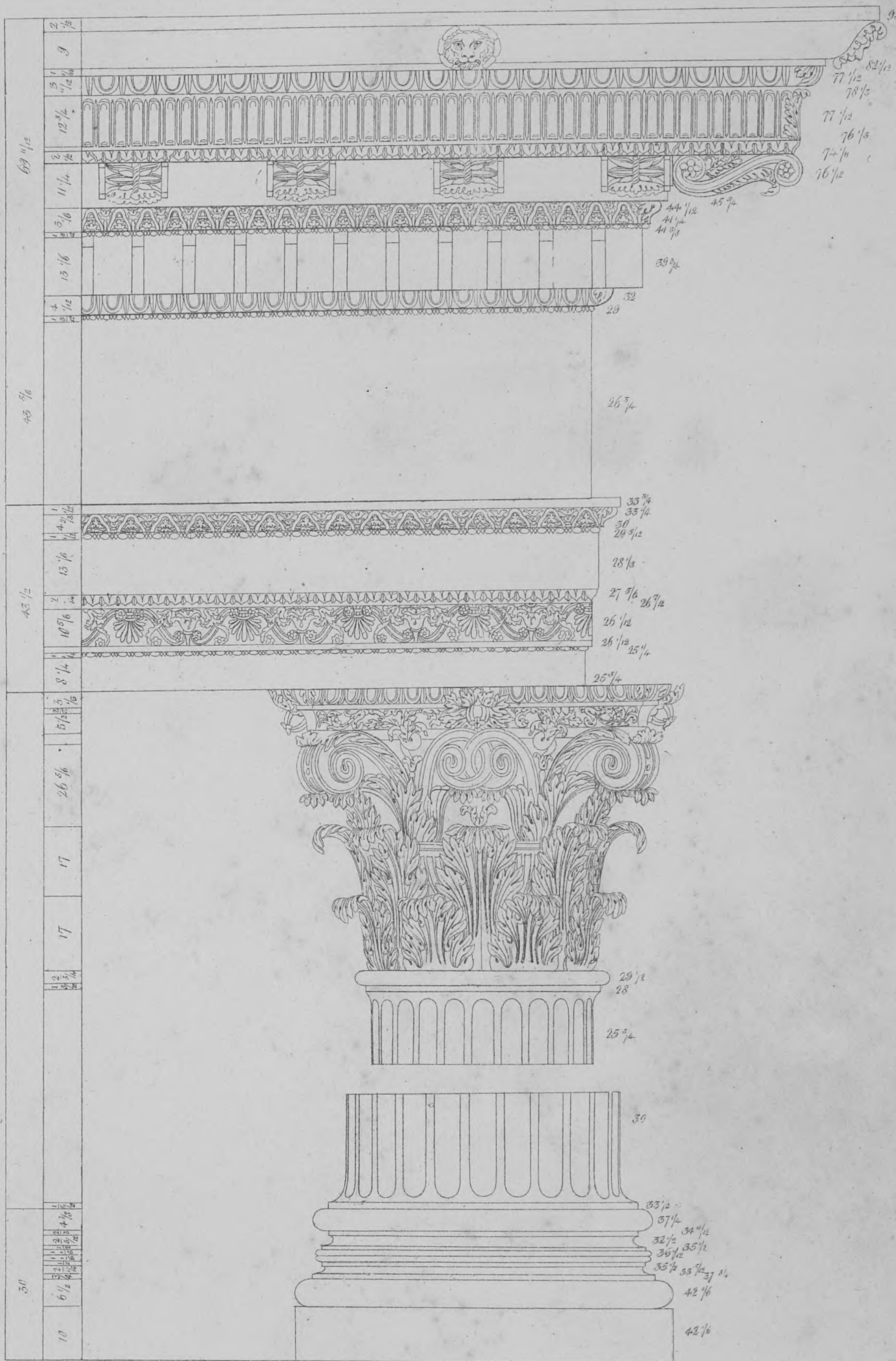


A. Gilbert R. Thew sc



...wn by P. Nicholson

...ngraved by R. Thew.



P. Nicholson

R. Thew sc.

CURB ROOF.

Fig. 1.

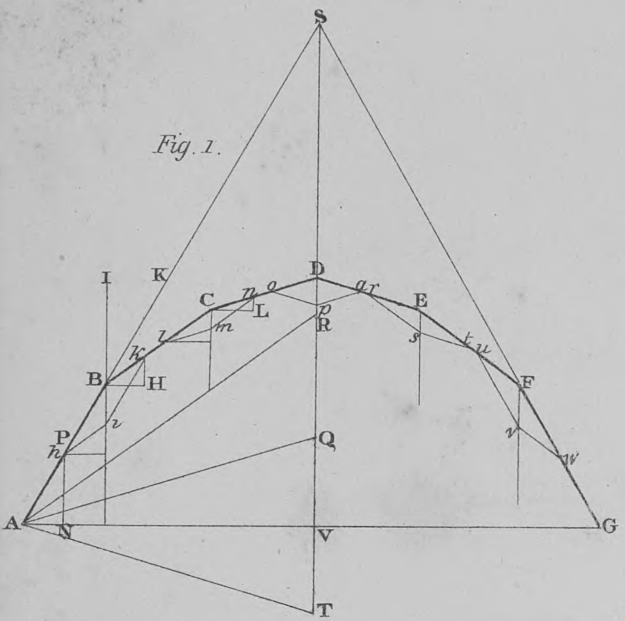


Fig. 2.

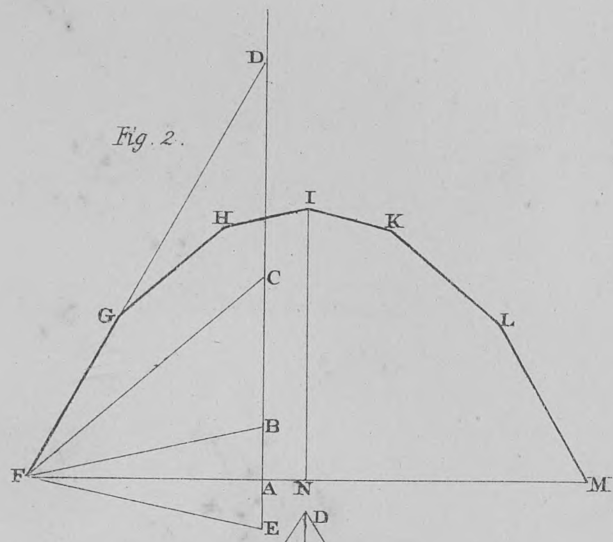


Fig. 3.

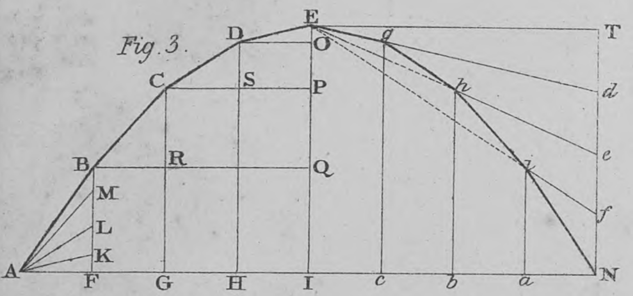


Fig. 4.

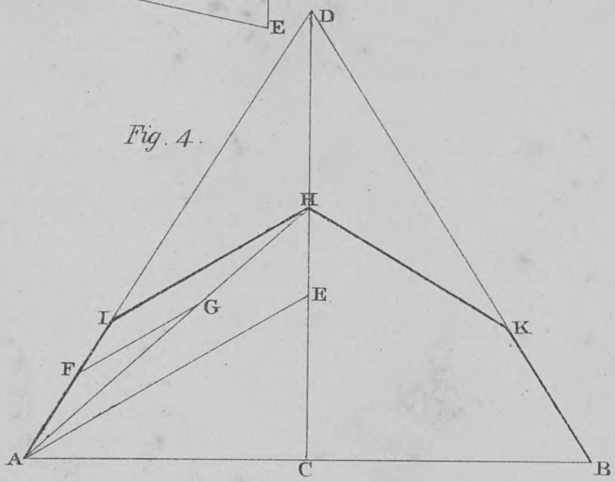


Fig. 5.

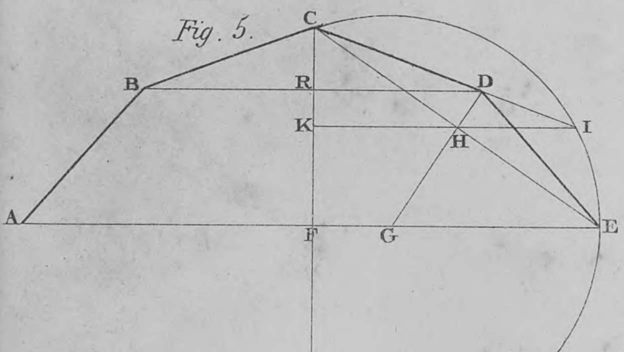
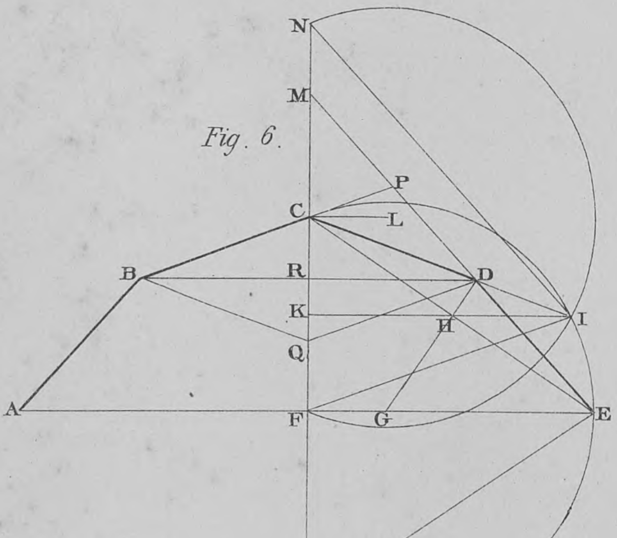


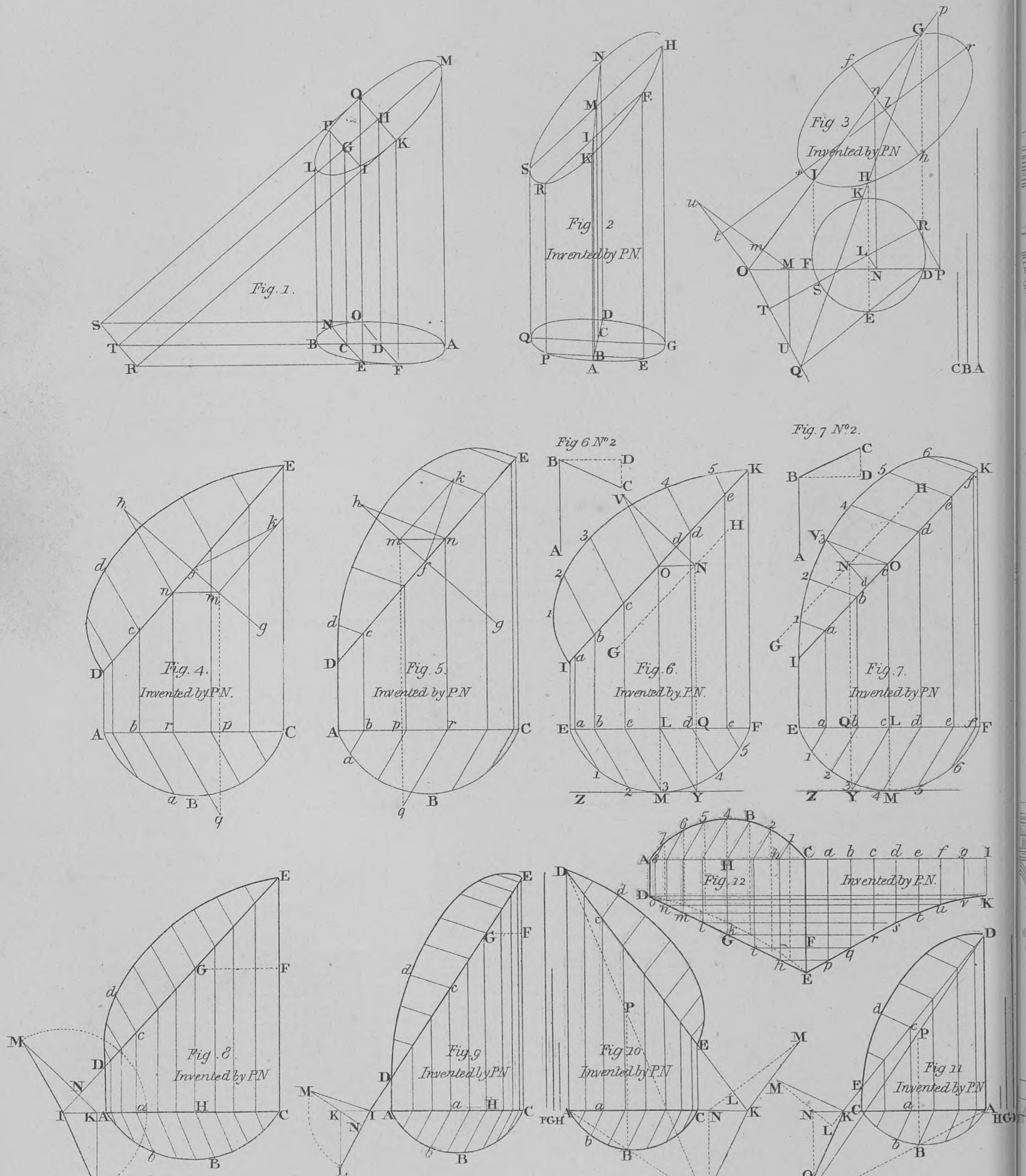
Fig. 6.



Invented & drawn by P. Nicholson.

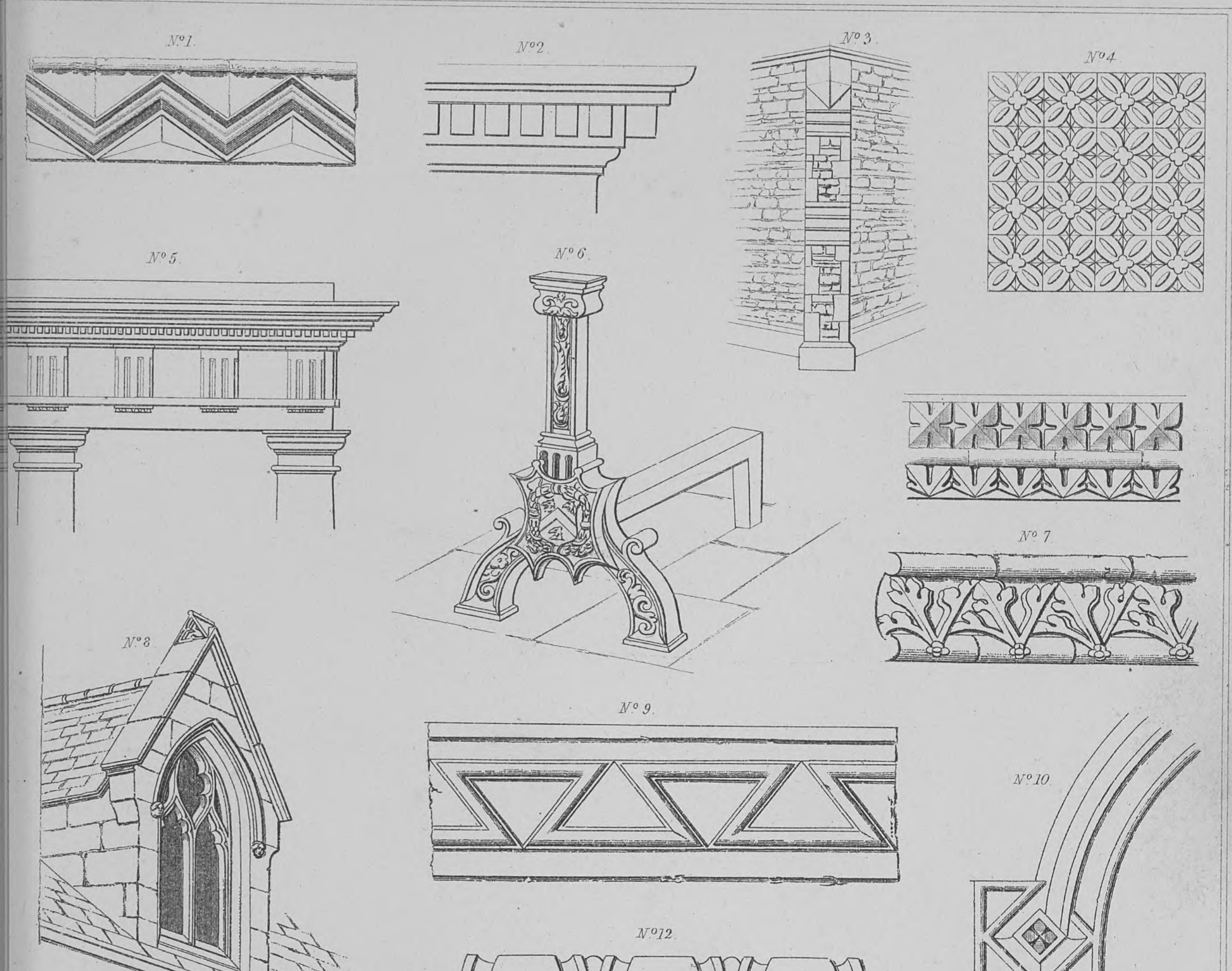
Eng^d by R. Thew.

PLATE I



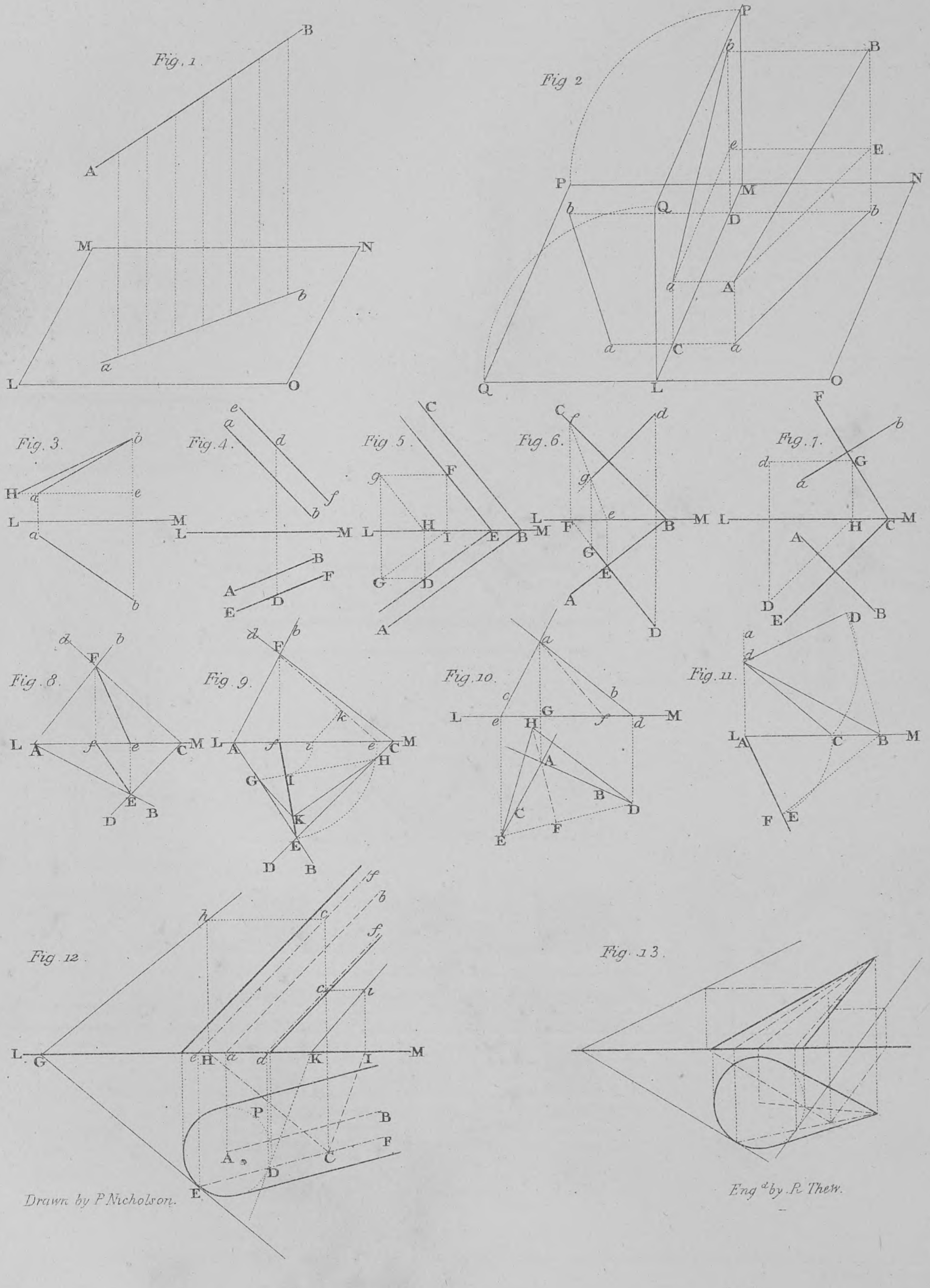
Drawn by P Nicholson.

Eng^d by R. Thew.



...ert Archt del. R. Thew Sc.

Nº 1. Dancette Moulding.
Nº 2. Dentil.
Nº 3. Diagonal Buttress.
Nº 4. Diaper.
Nº 5. Ditriglyph.
Nº 6. Dogs.
Nº 7. Dogtooth Moulding.
Nº 8. Dormer.
Nº 9. Dovetail Moulding.
Nº 10. Dripstone.
Nº 11. Drops.
Nº 12. Eggs.
Nº 13. Engaged Column.
Nº 14. Entablature.
Nº 15. Entresole.



Drawn by P. Nicholson.

Eng^d by R. Thew.

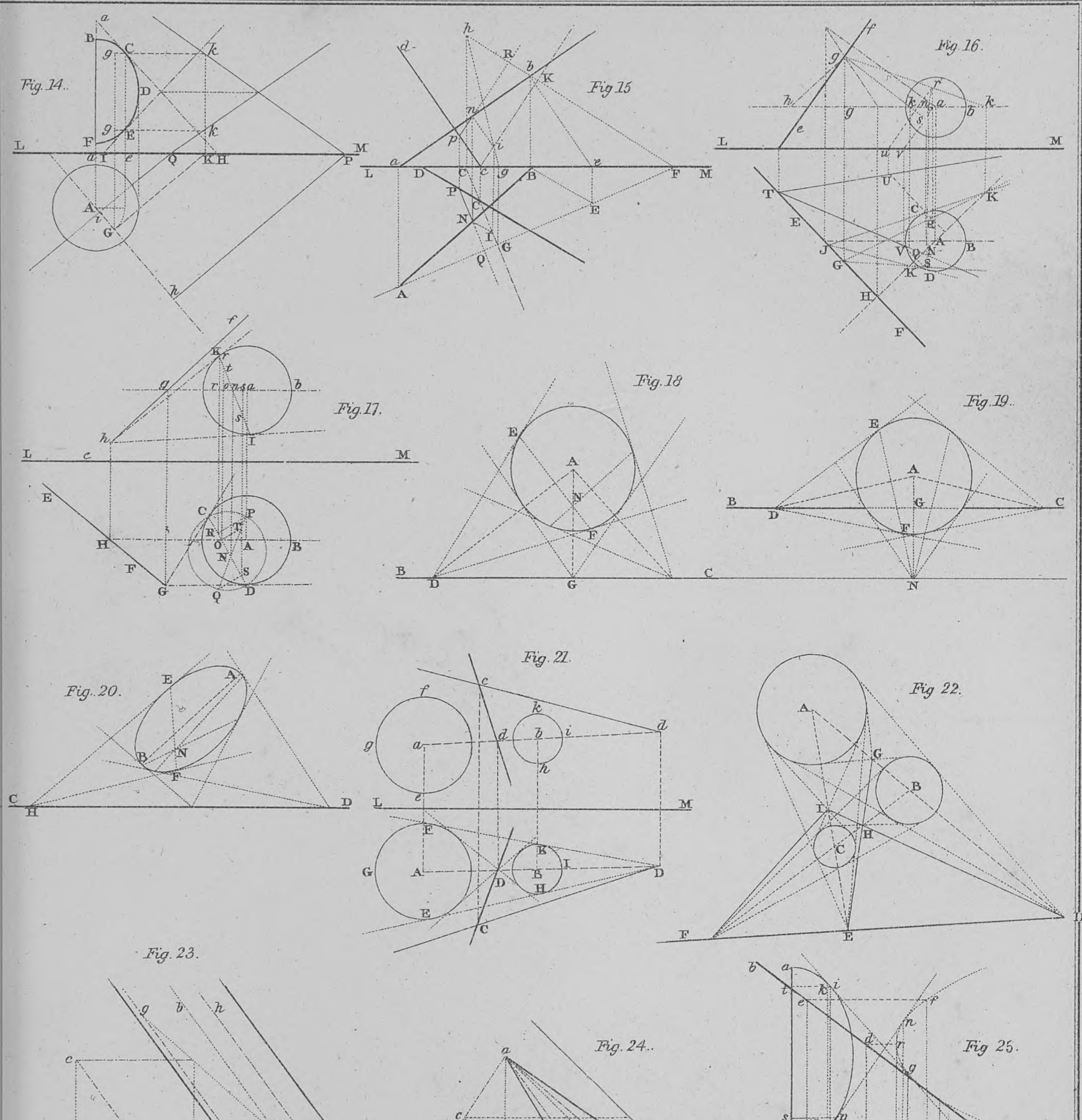
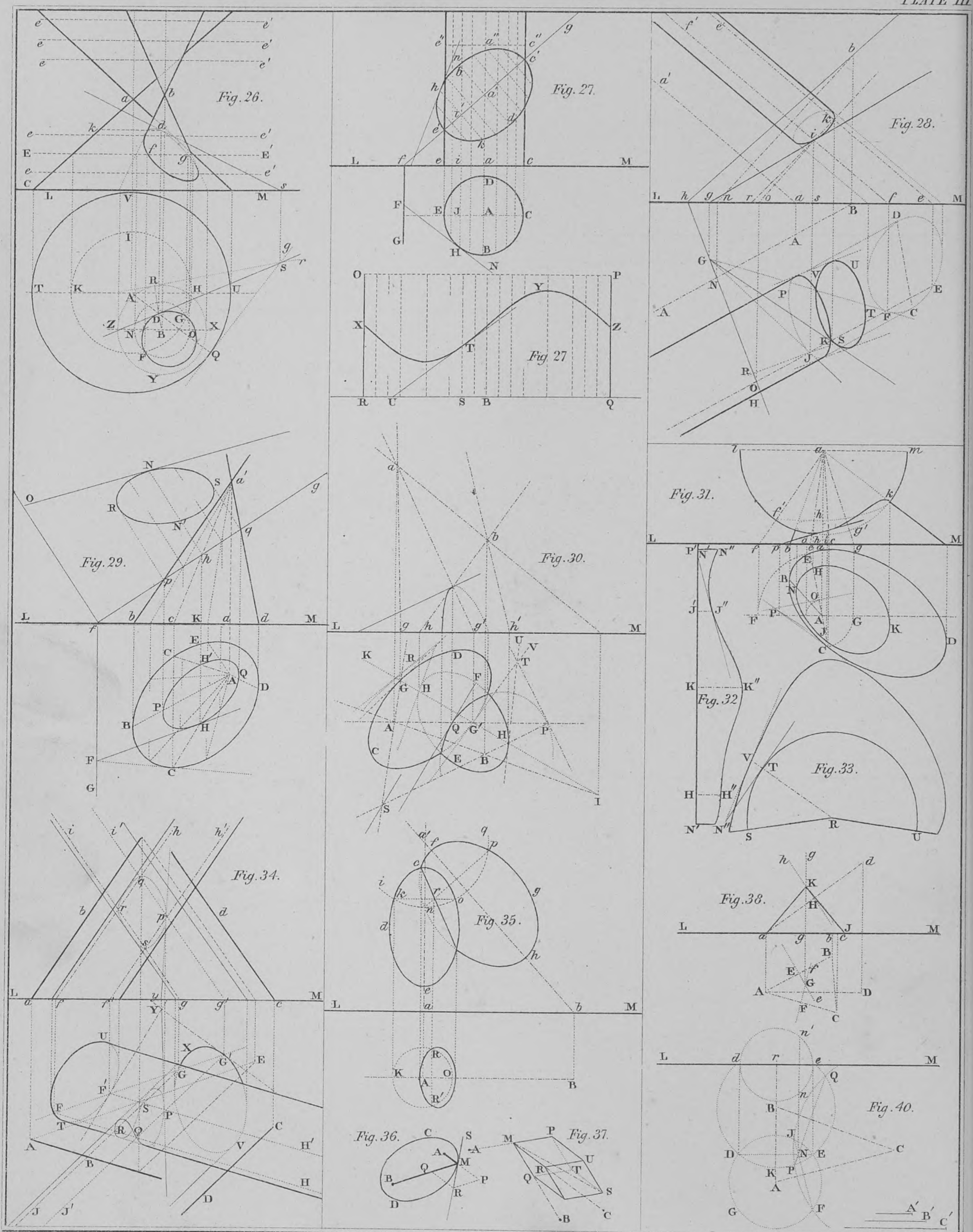


Fig. 14. Fig. 15. Fig. 16. Fig. 17. Fig. 18. Fig. 19. Fig. 20. Fig. 21. Fig. 22. Fig. 23. Fig. 24. Fig. 25.

Drawn by M. A. Nicholson. Engd. by R. Thew.

DESCRIPTIVE GEOMETRY.

PLATE III



Drawn by M A Nicholson.

Engraved by R Thew.

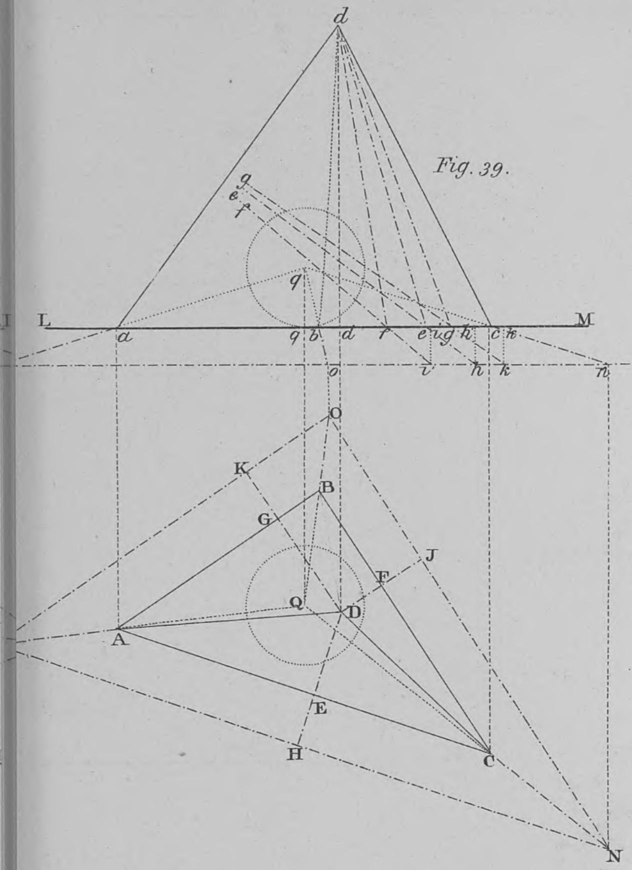


Fig. 39.

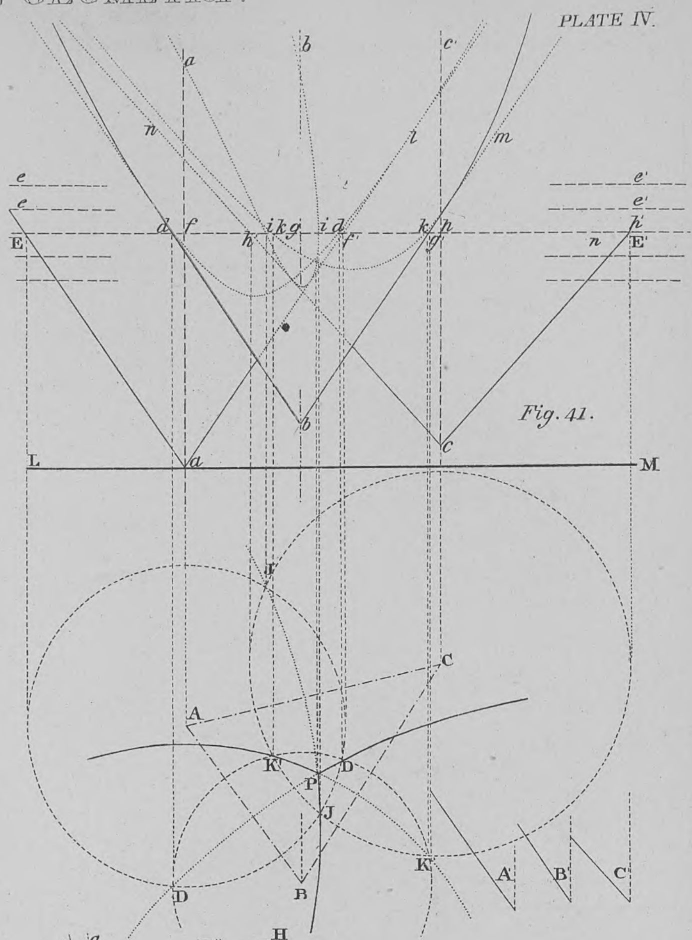


Fig. 41.

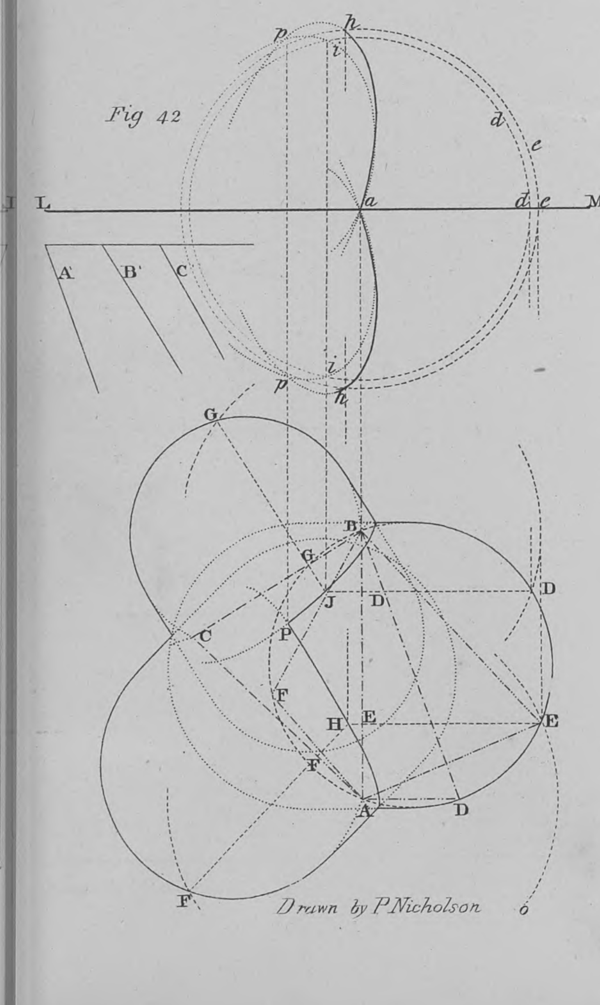
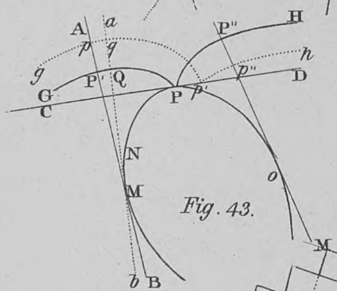


Fig 42



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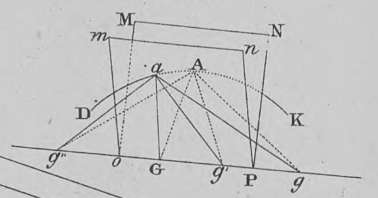

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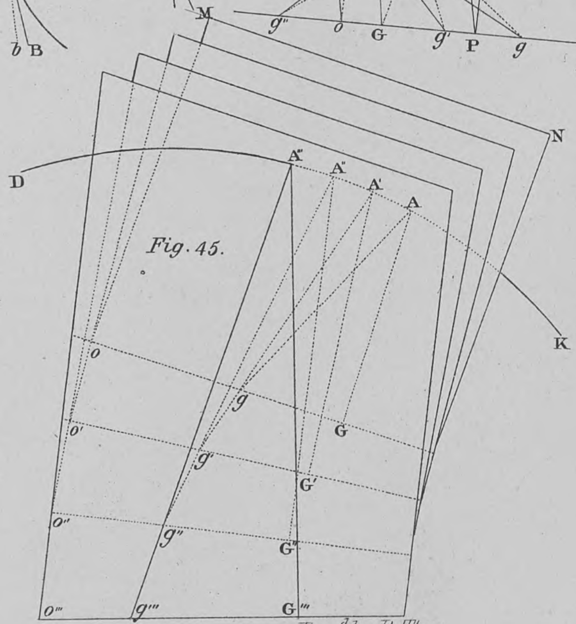


Fig. 45.

Drawn by P. Nicholson

Eng^d by R. Thew.

Fig. 1. N° 2

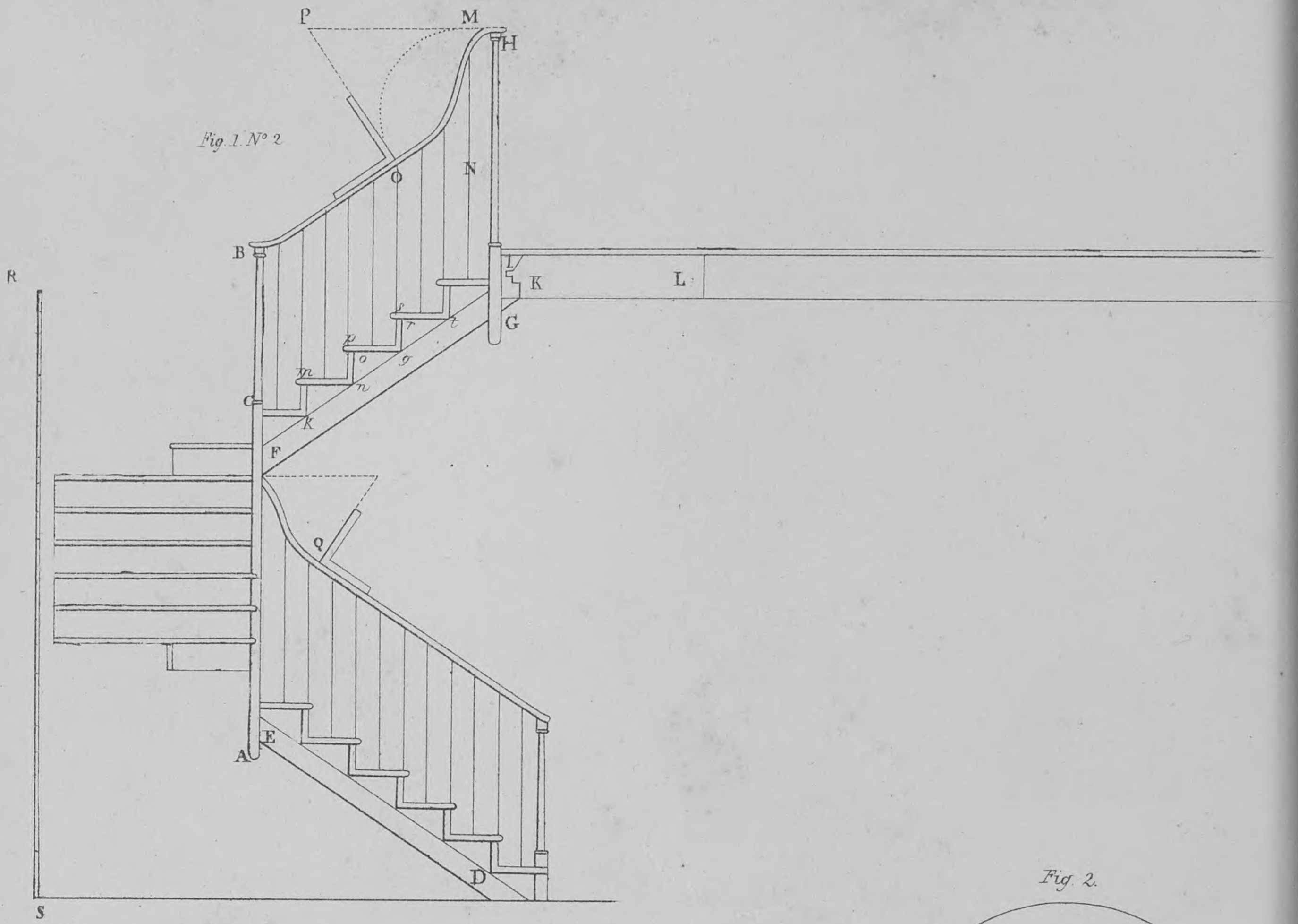


Fig. 2.

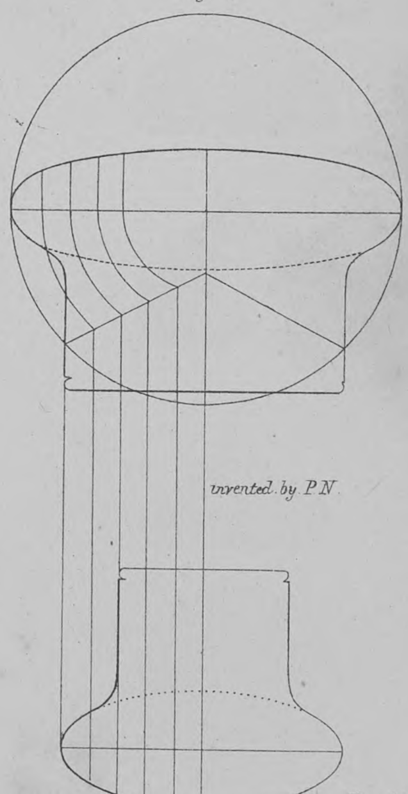
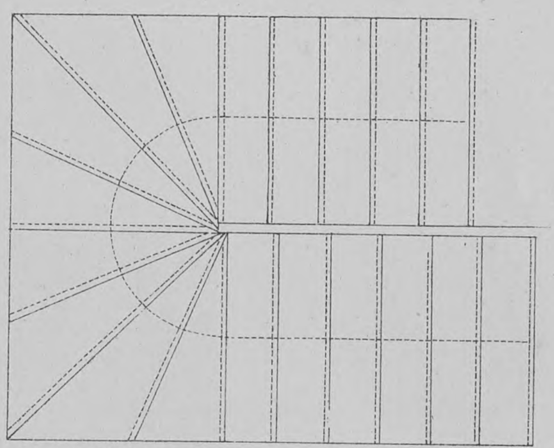


Fig. 1. N° 1.

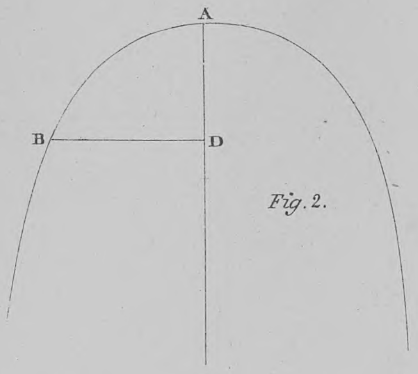


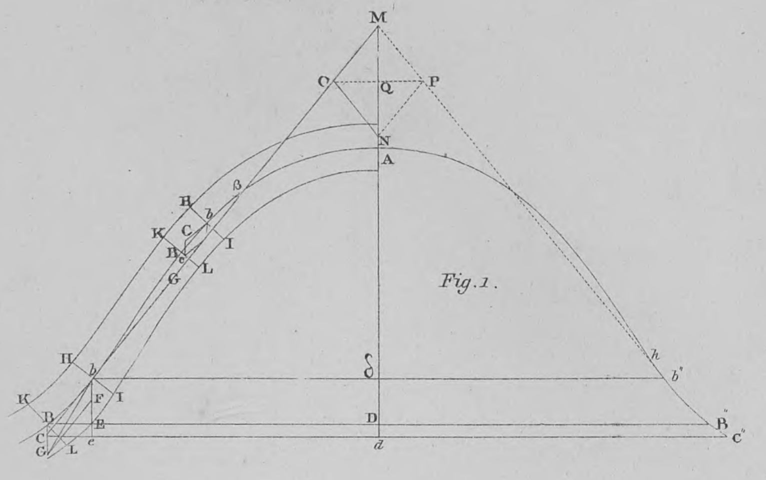
Drawn by P. Nicholson.

Eng^d by R.

DOME.

PLATE.I.





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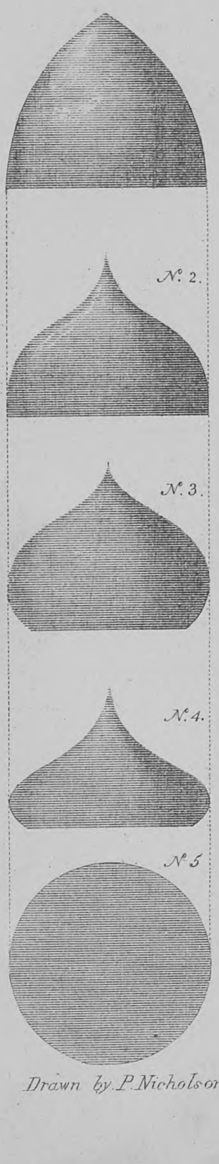


Fig. 5. No. 1.

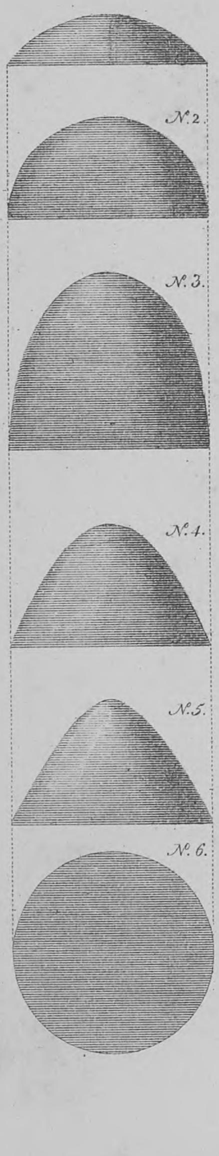


Fig. 4. No. 1.

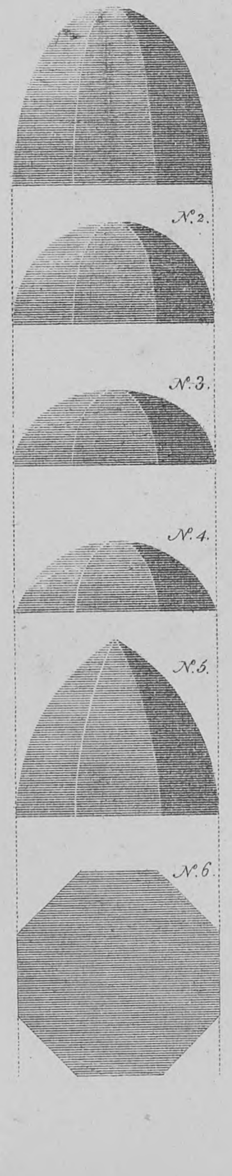


Fig 3 No. 1.

Drawn by P. Nicholson.

Eng^d by R. Thew.

Fig. 1.

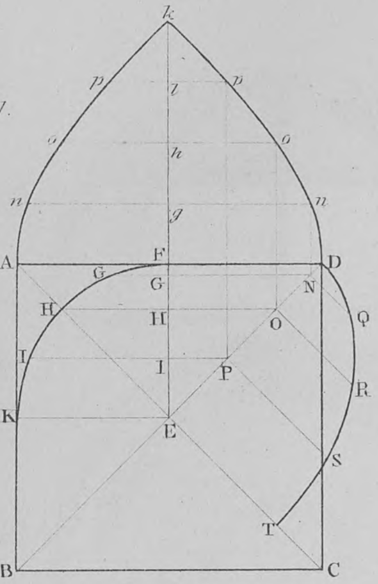


Fig. 2.

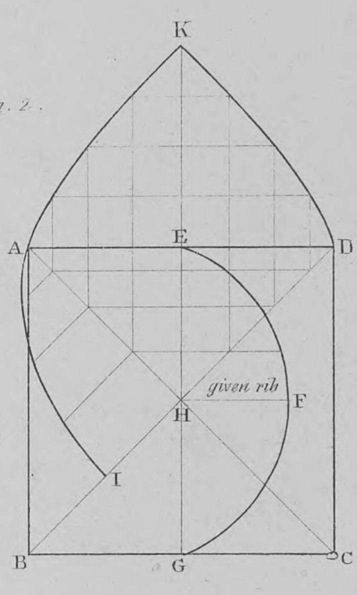


Fig. 3.

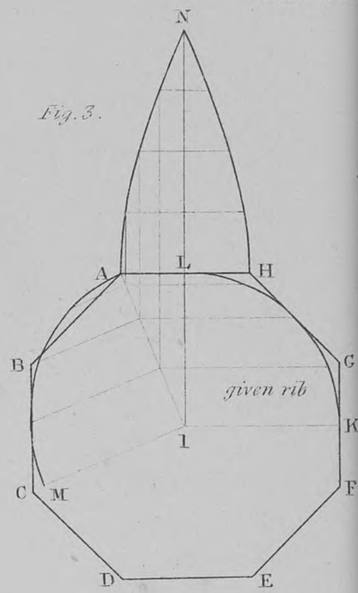
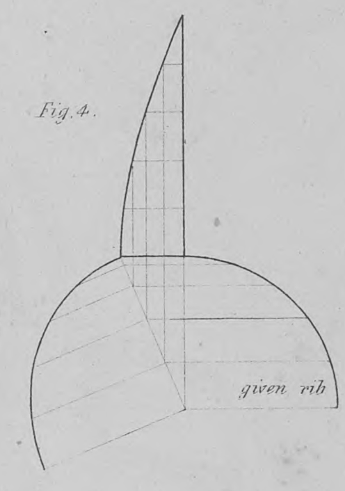


Fig. 4.



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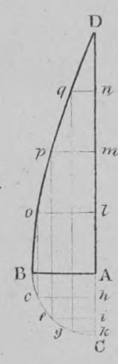


Fig. 6.

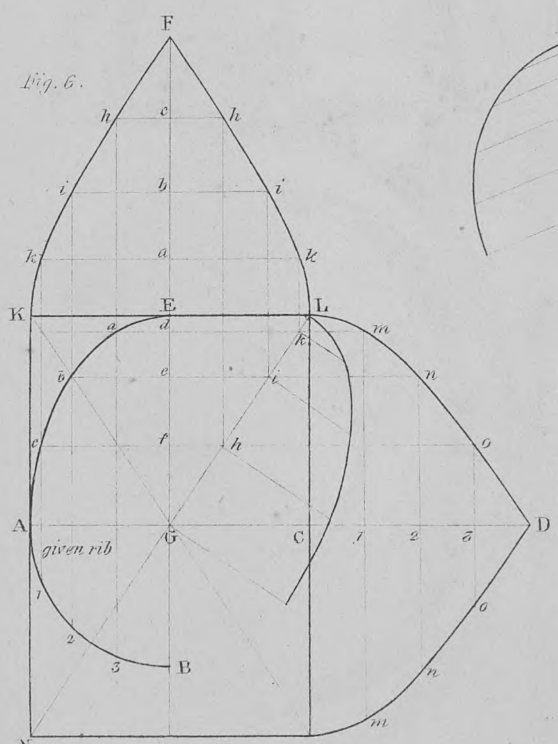
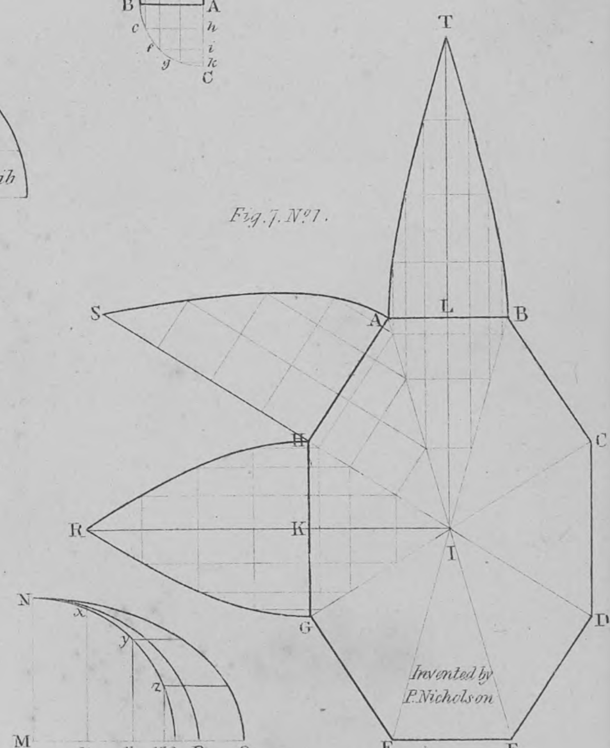


Fig. 7. N°1.

Fig. 7. N°2.



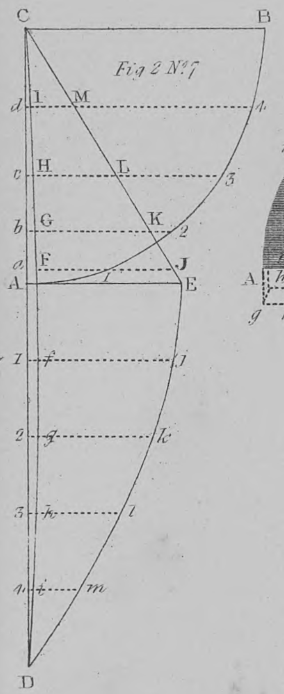


Fig 2 No. 7

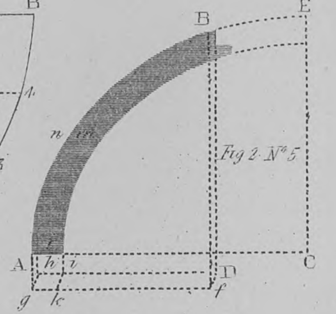


Fig 2 No. 5

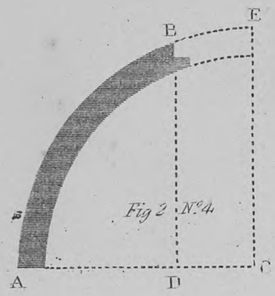


Fig 2 No. 4

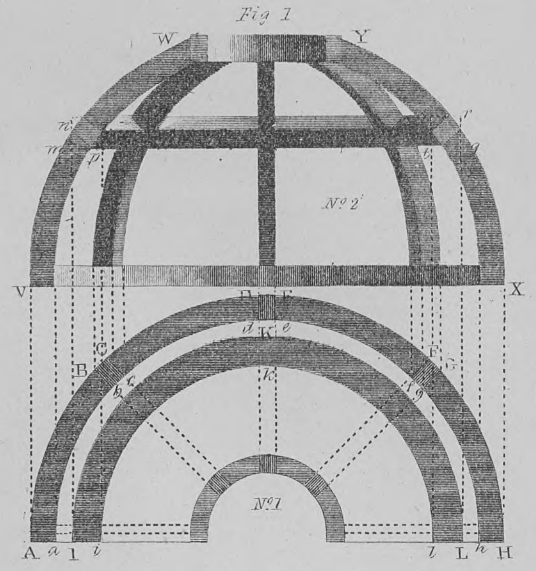


Fig 1

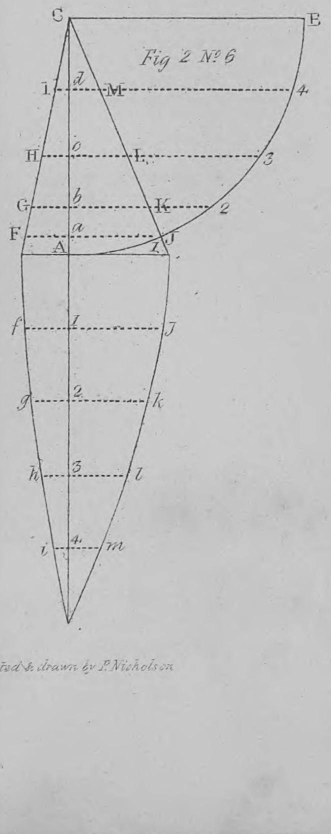


Fig 2 No. 6

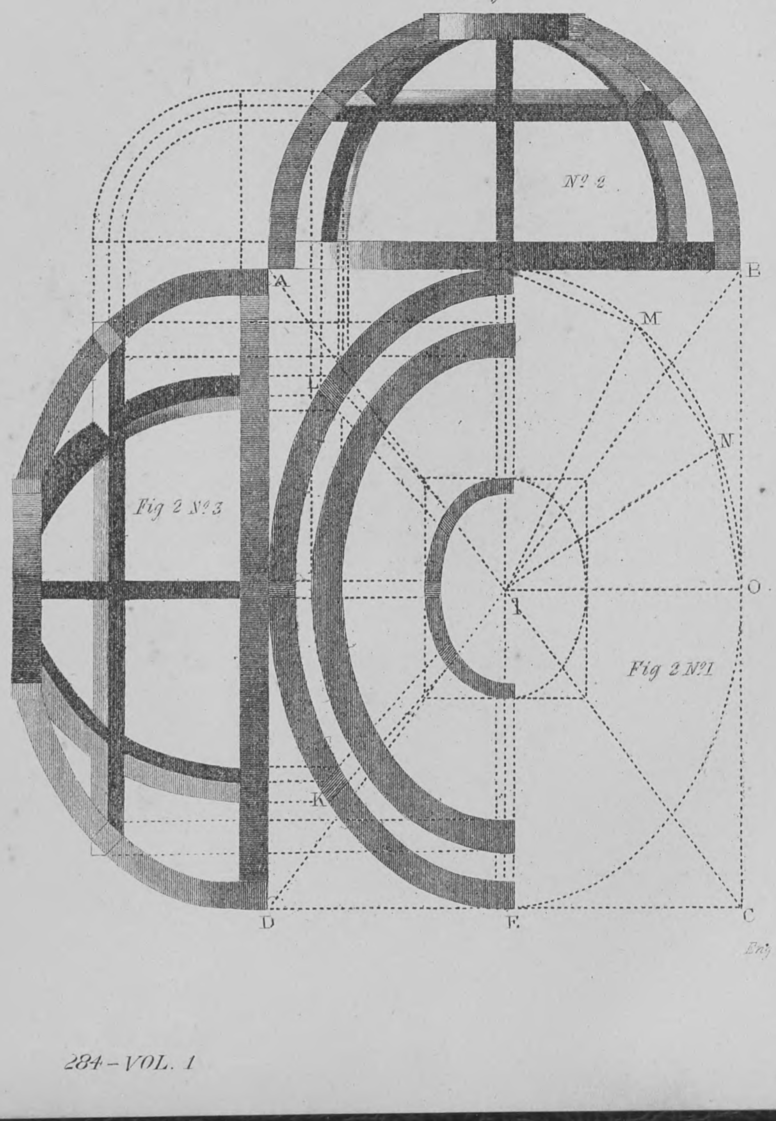
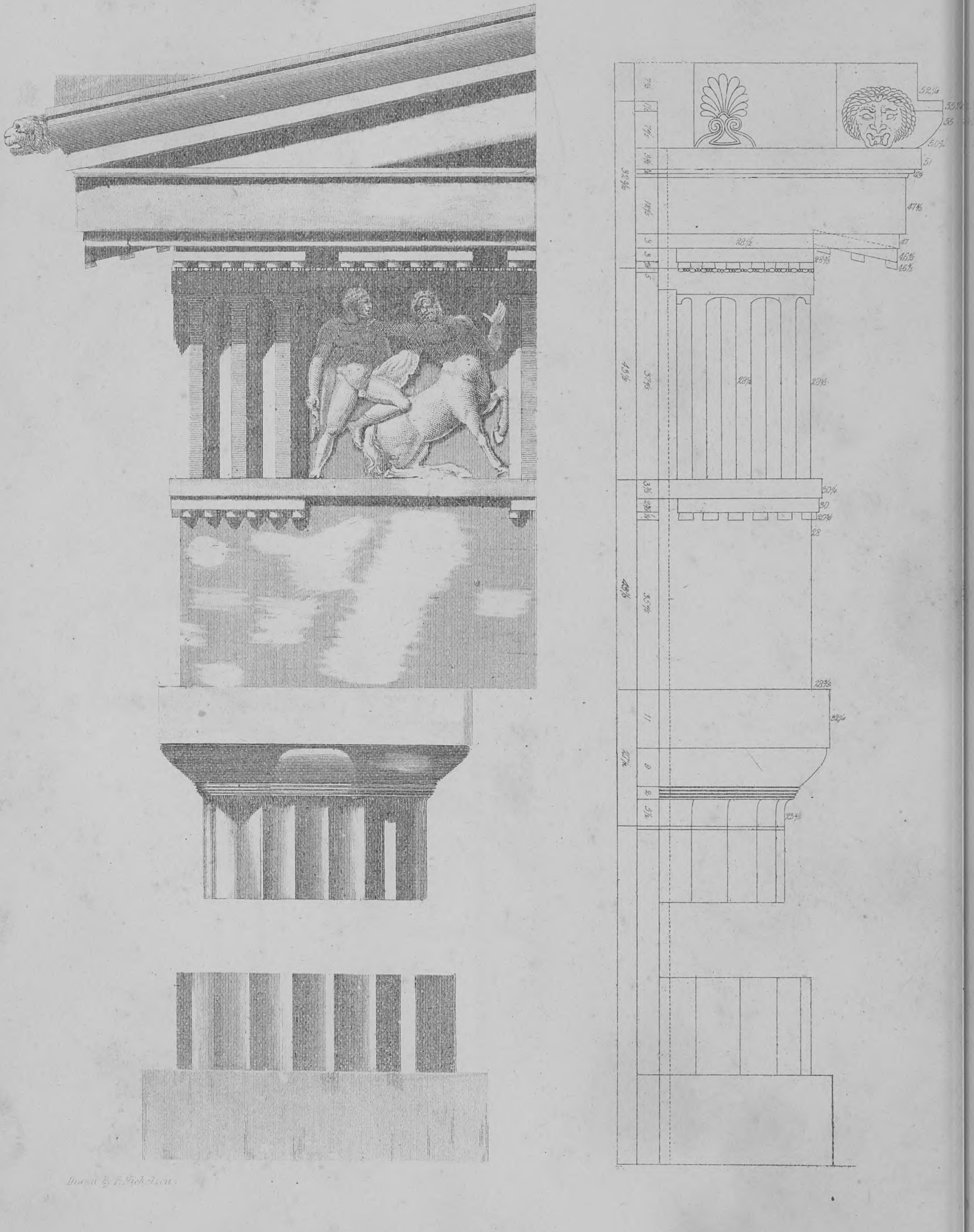


Fig 2

Invented & drawn by P. Nicholson

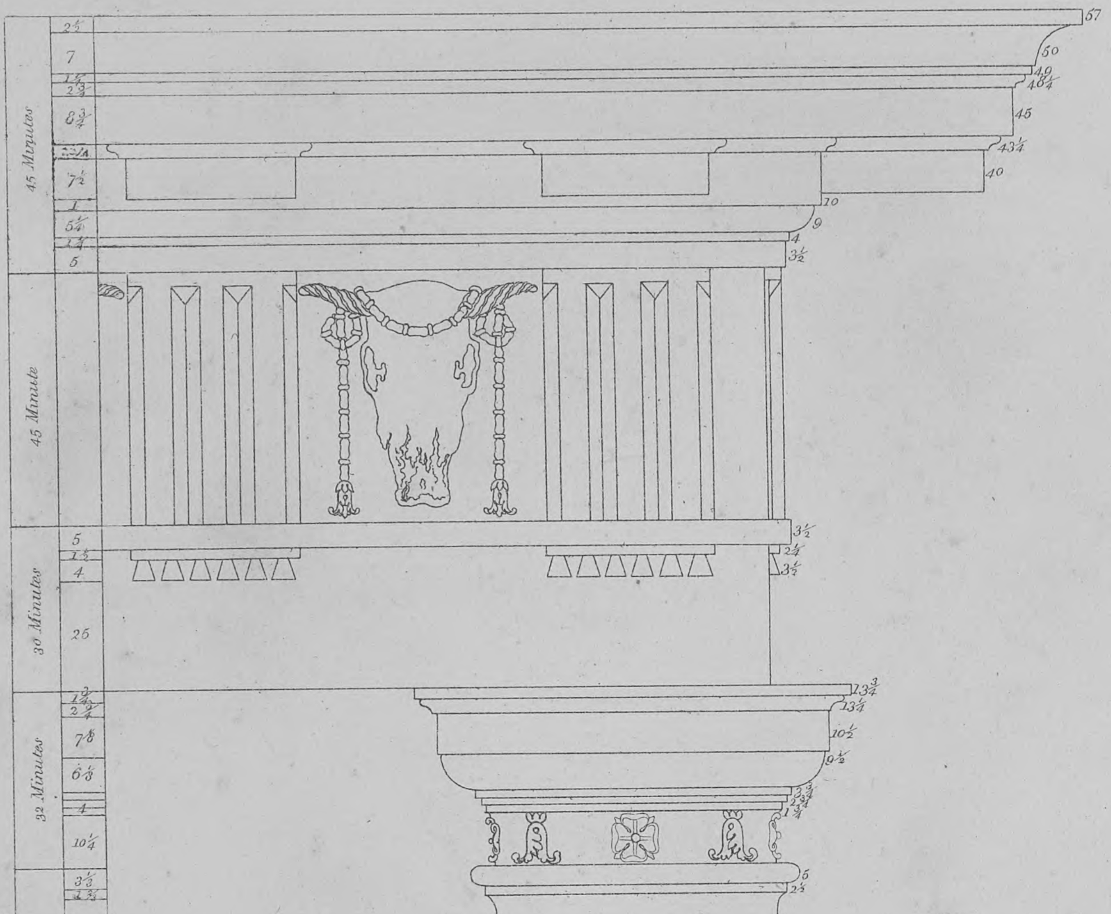
Engd by R. Thew



Drawn by P. Nicholson.

DORIC ORDER, PLATE 2.

FROM SIR WILLIAM CHAMBERS.

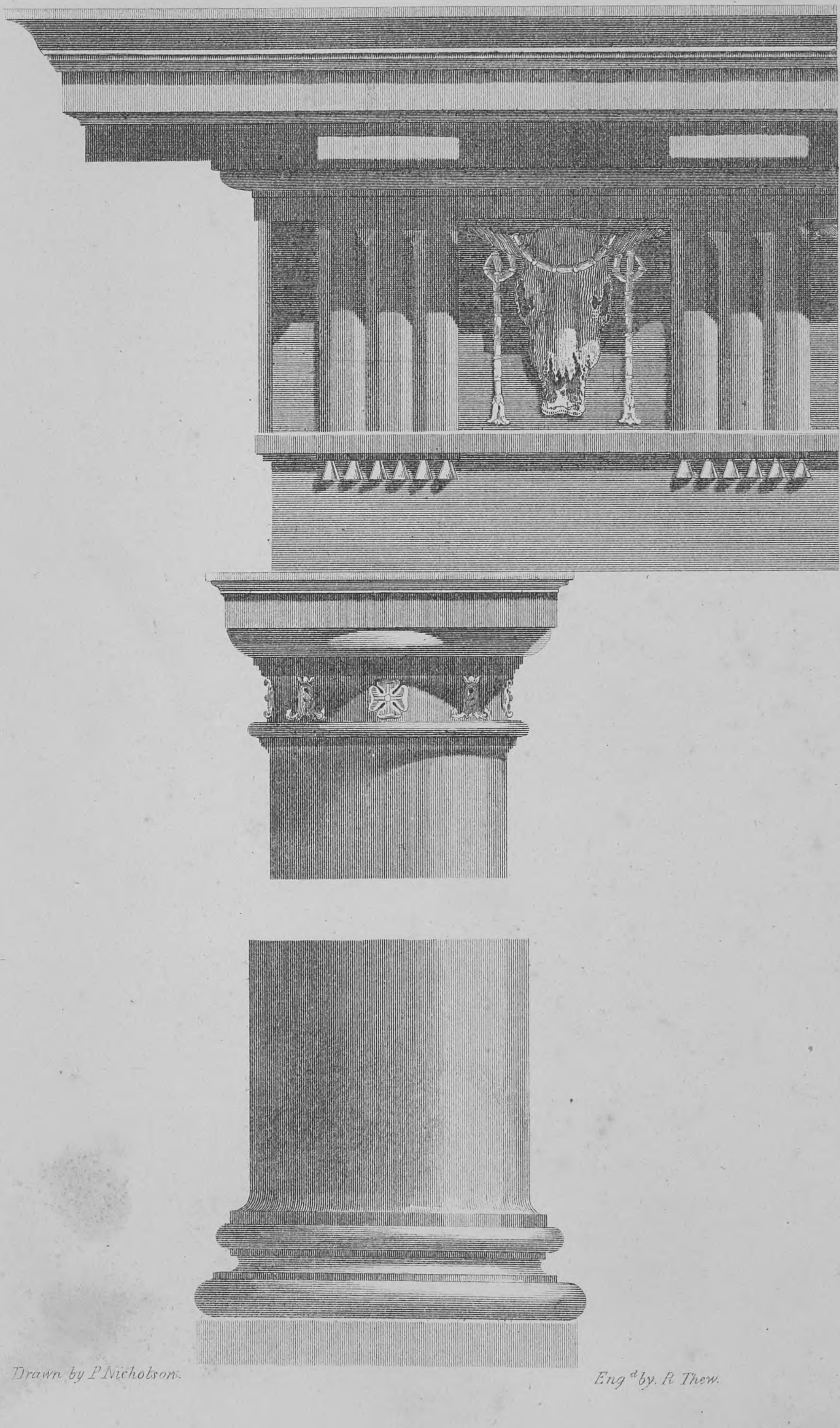


Drawn by P. Nicholson.

Eng.d by R. Thew.

DORIC ORDER, PLATE, III.

MODERN.



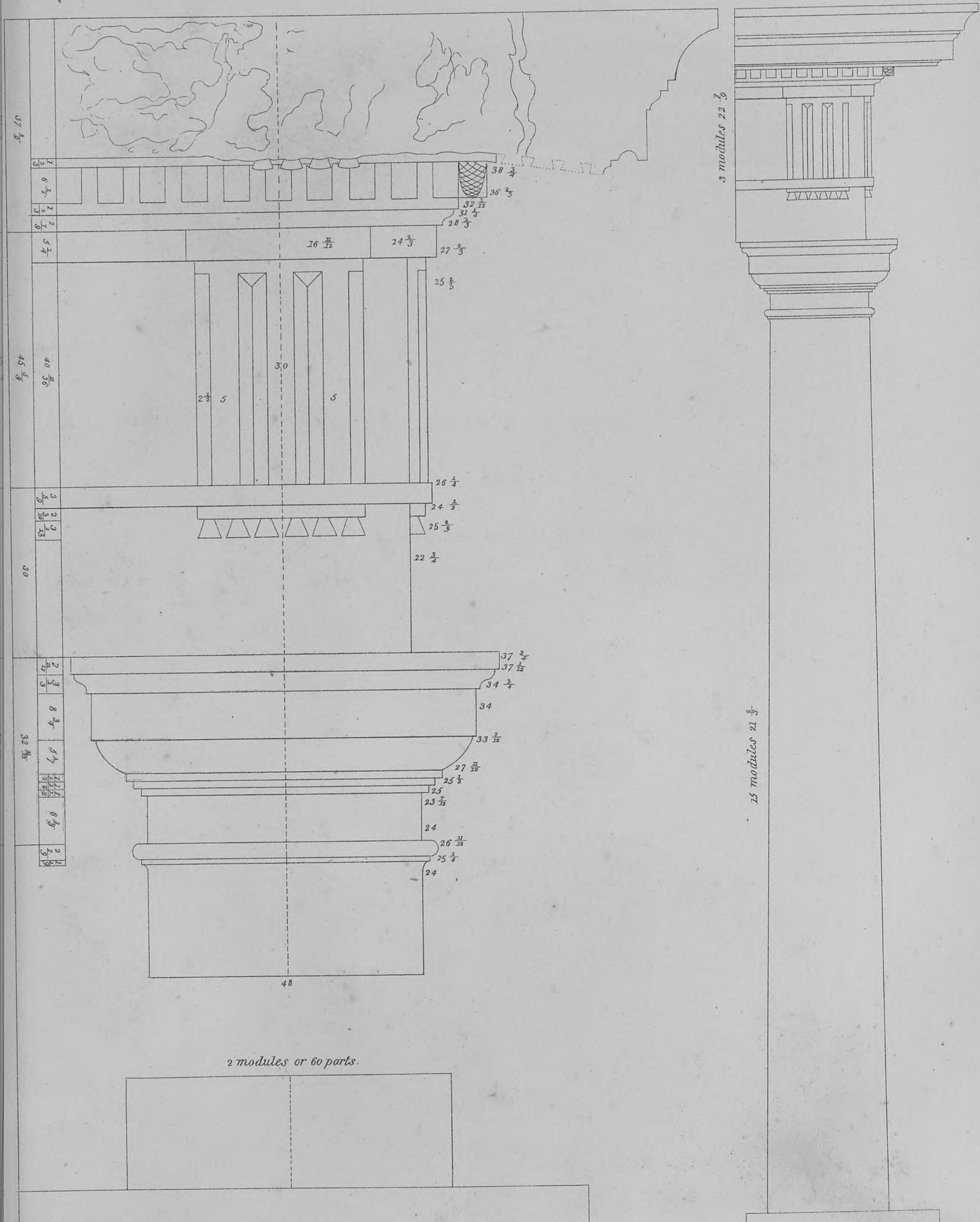
Drawn by P. Nicholson.

Eng^{d} by. R. Thew.

DORIC ORDER.

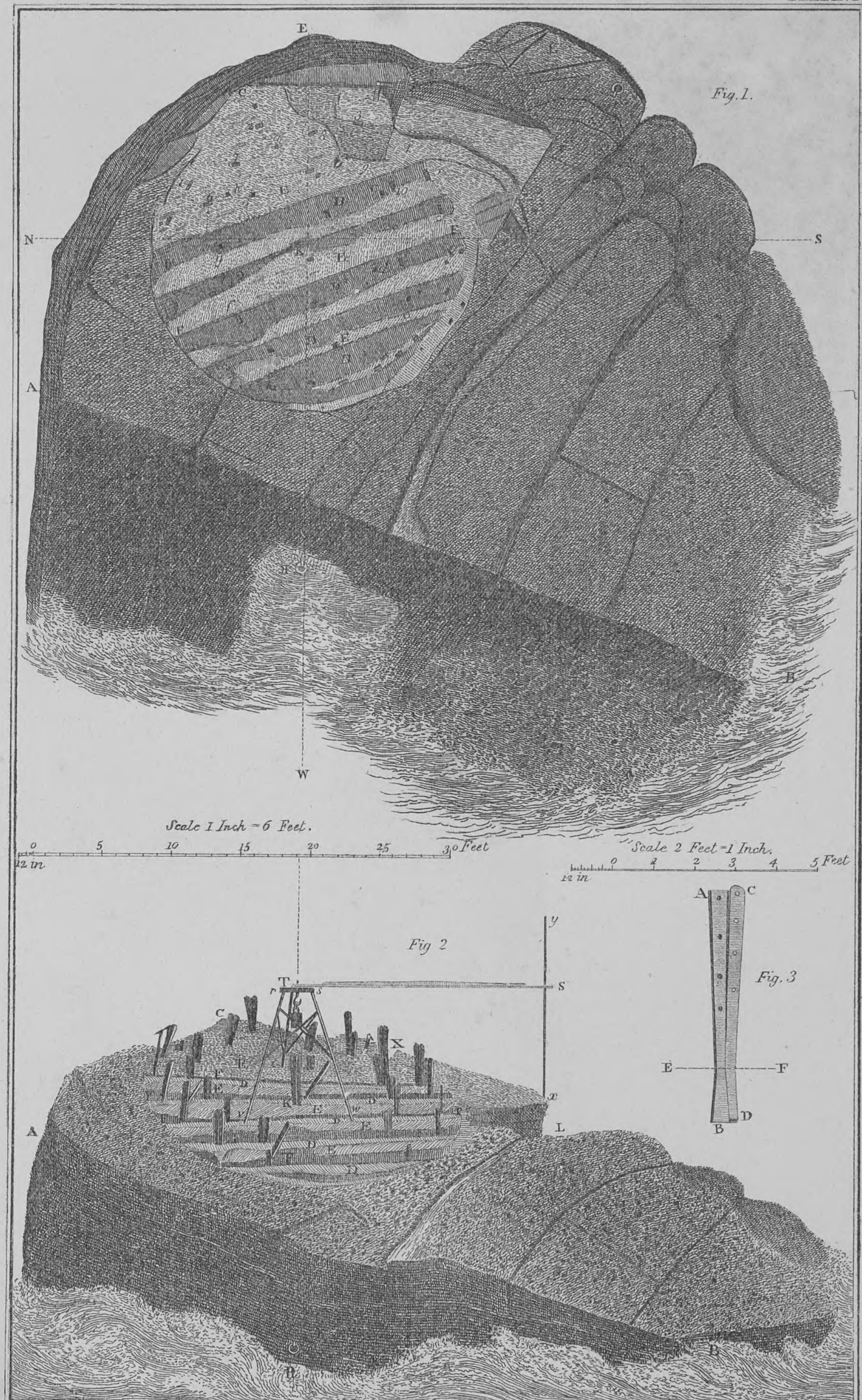
FROM THE THEATRE OF MARCELLUS AT ROME.

PLATE IV.



Drawn by P. Nicholson.

Eng.d by R. Thew.



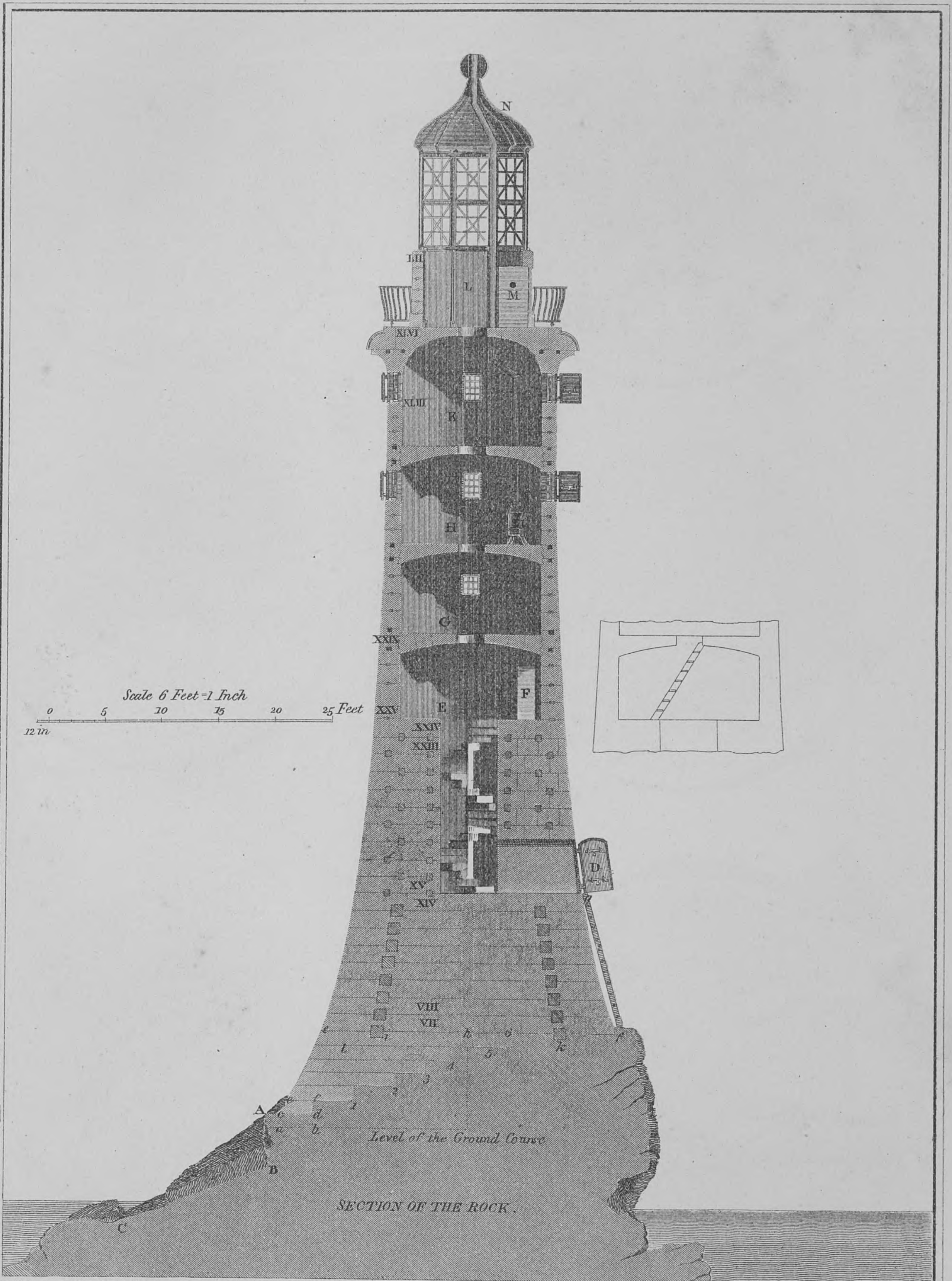
Drawn by M A Nicholson

Engd. by R Thew.

EDDYSTONE LIGHT HOUSE. PLATE II. Nº 1.

Drawn by M A Nicholson. *Engraved by R. Thew.*

5 10 15 20 25 Feet.



Drawn by M A Nicholson.

Engd by. R Thew.

Fig. 3.

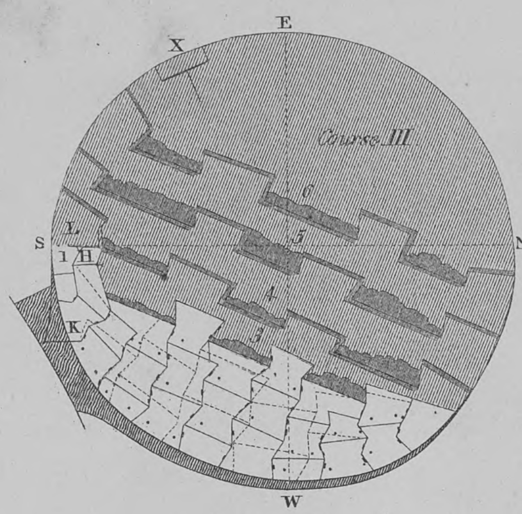


Fig. 6.

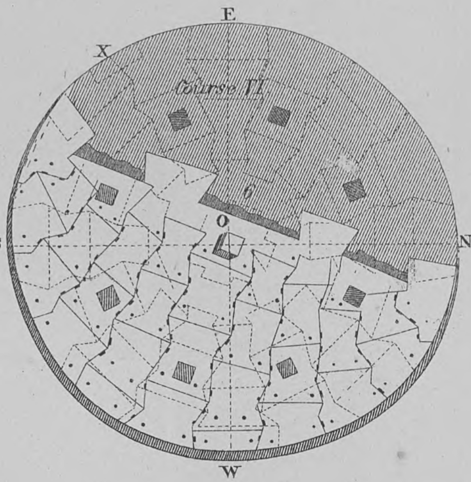


Fig. 2.

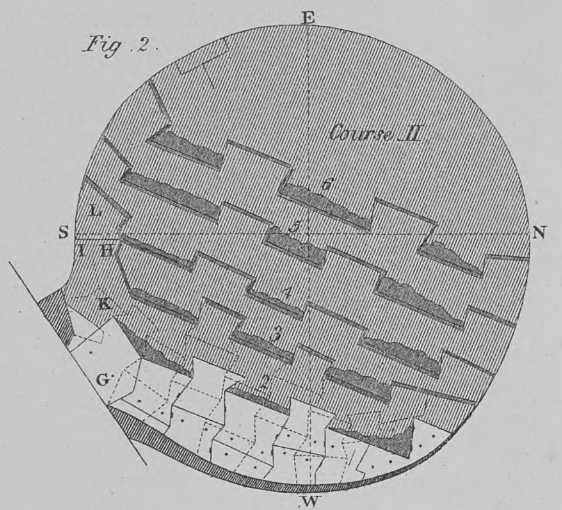


Fig. 5.

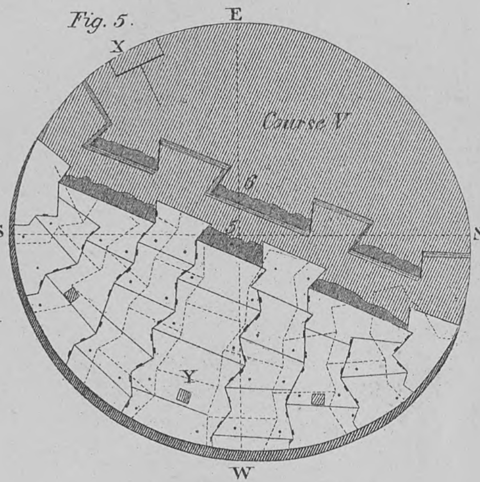


Fig. 1.

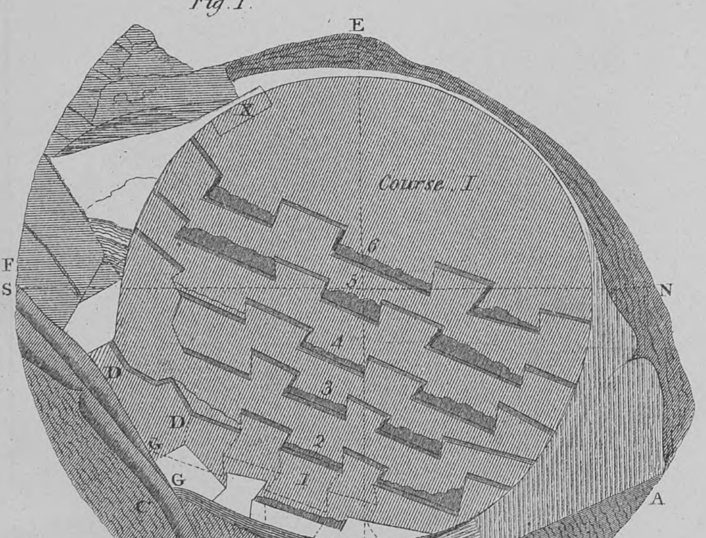
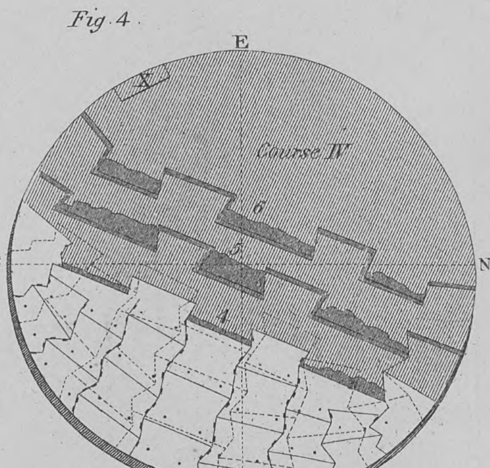
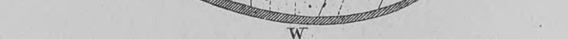


Fig. 4.

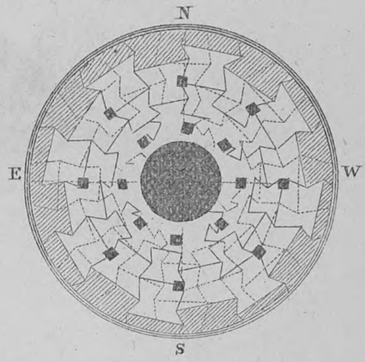




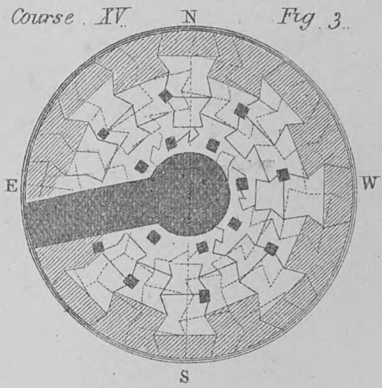
Drawn by. M.A. Nicholson.

Eng.^d by. R. Thew.

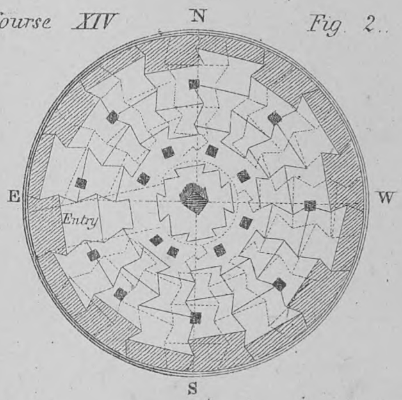
Course. XVIII. Fig. 4.



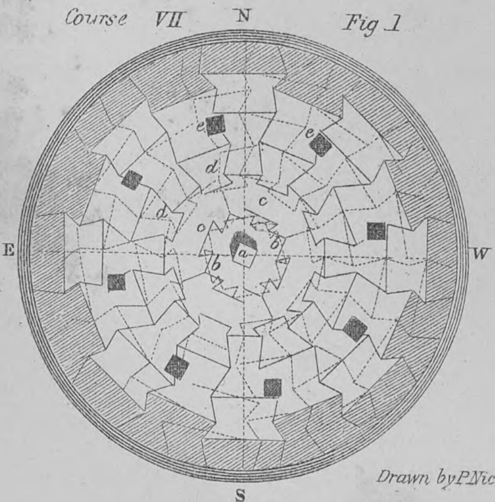
Course. XV. Fig. 3.



Course XIV Fig. 2.

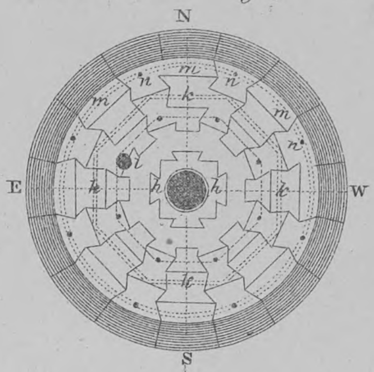


Course VII Fig. 1

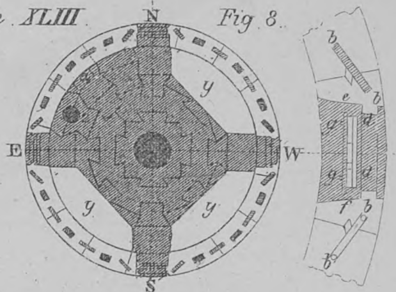


Drawn by P. Nicholson.

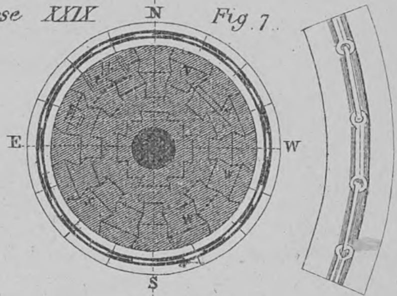
Course. XLVI. Fig. 9.



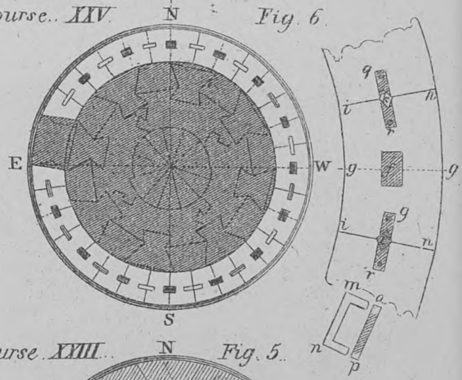
Course. XLIII. Fig. 8.



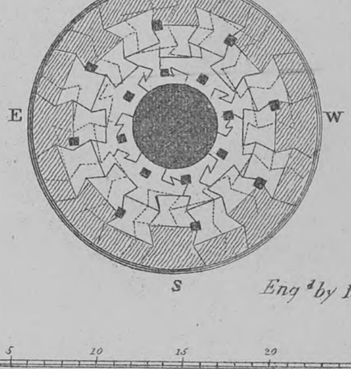
Course XXIX Fig. 7.



Course.. XXV. Fig. 6.



Course. XXIII. Fig. 5.



Eng.d by R. Thew.

5 10 15 20 25 30 feet

Fig. 2.

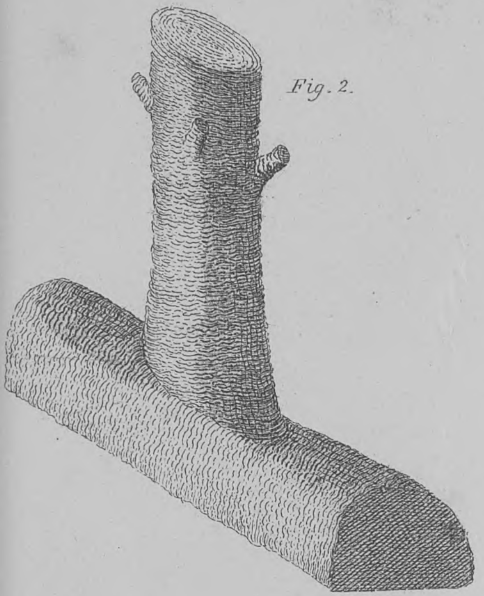
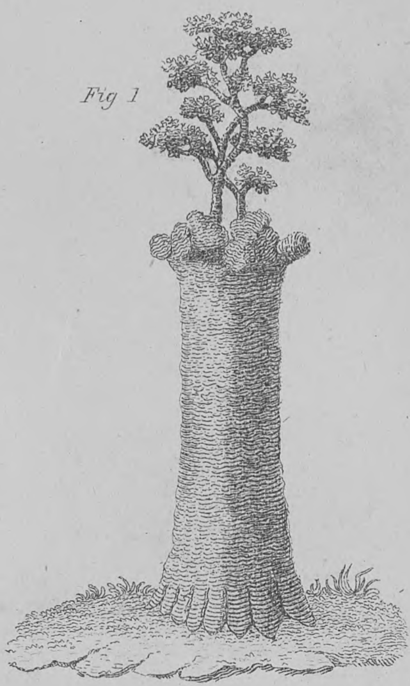


Fig 1



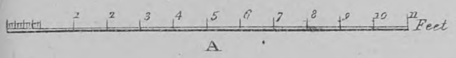


Fig. 5.

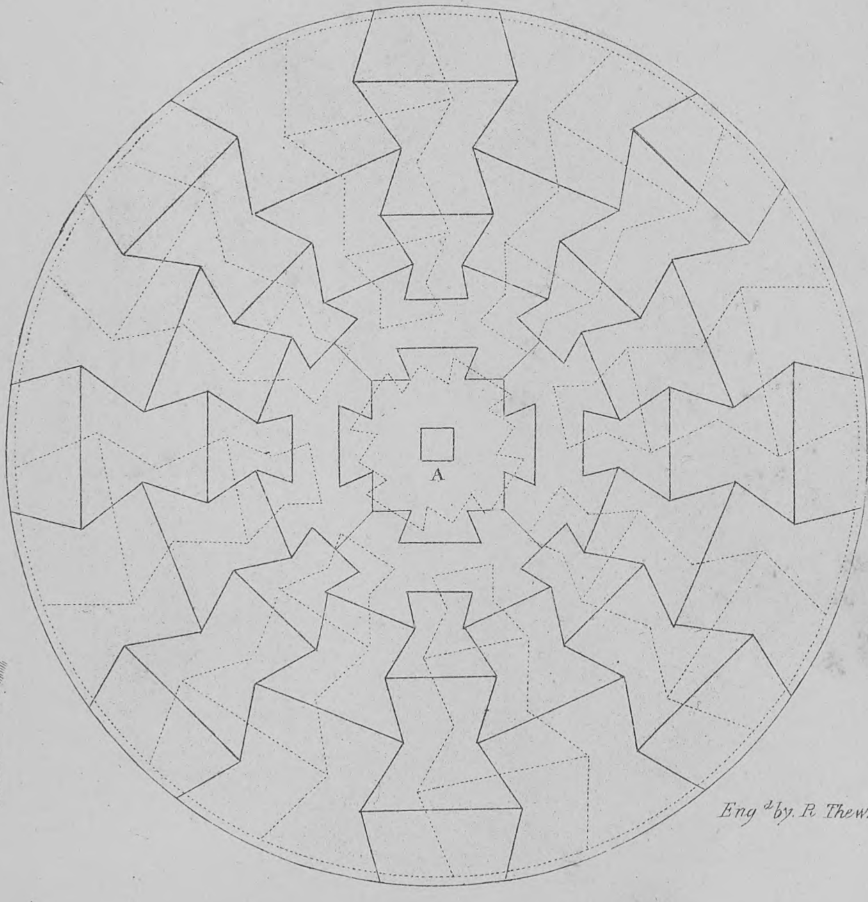


Fig. 4.

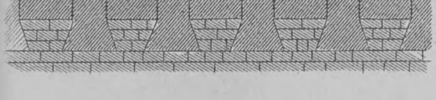
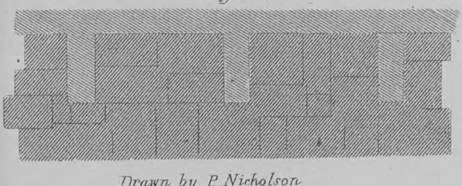


Fig. 3.



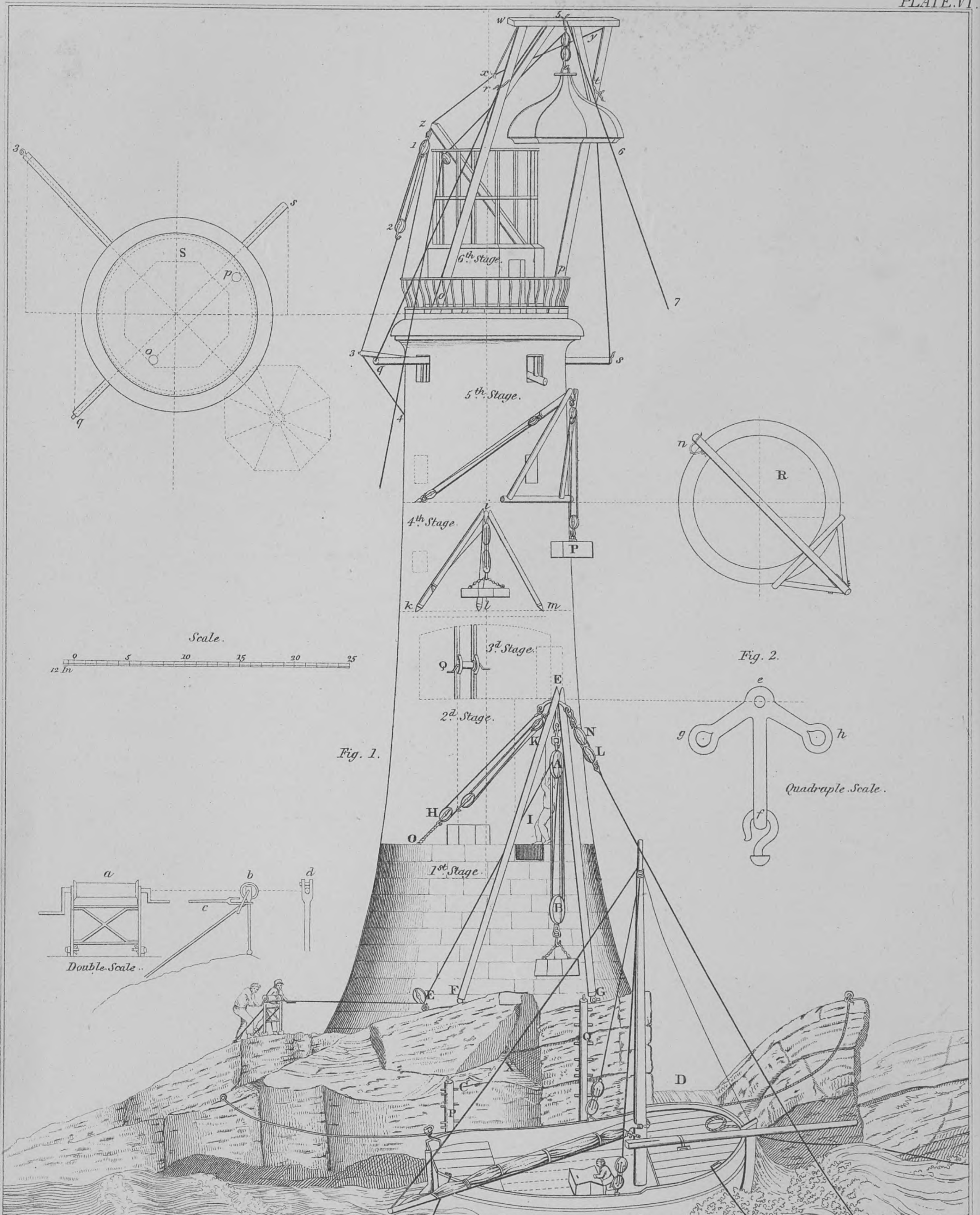
Drawn by P. Nicholson

Eng^d by. R. Thew.

LIGHT HOUSE

A View of the Rock on the East side and of the work advanced to course XV, being the first of the Entry courses, shewing the manner of Landing and Hoisting the stones &c, in every stage of the Building.

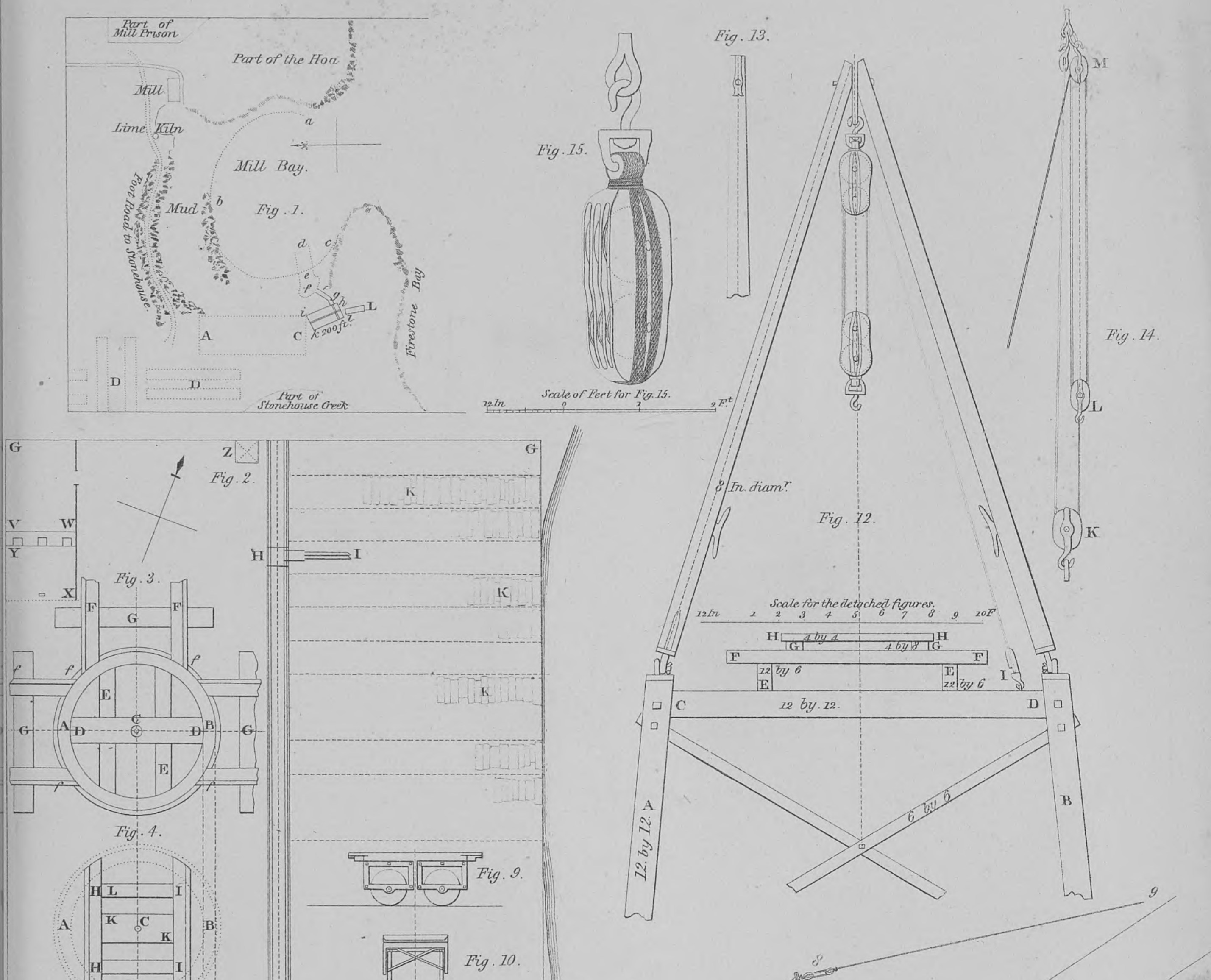
PLATE.VI.



Engd. by R. Thew.

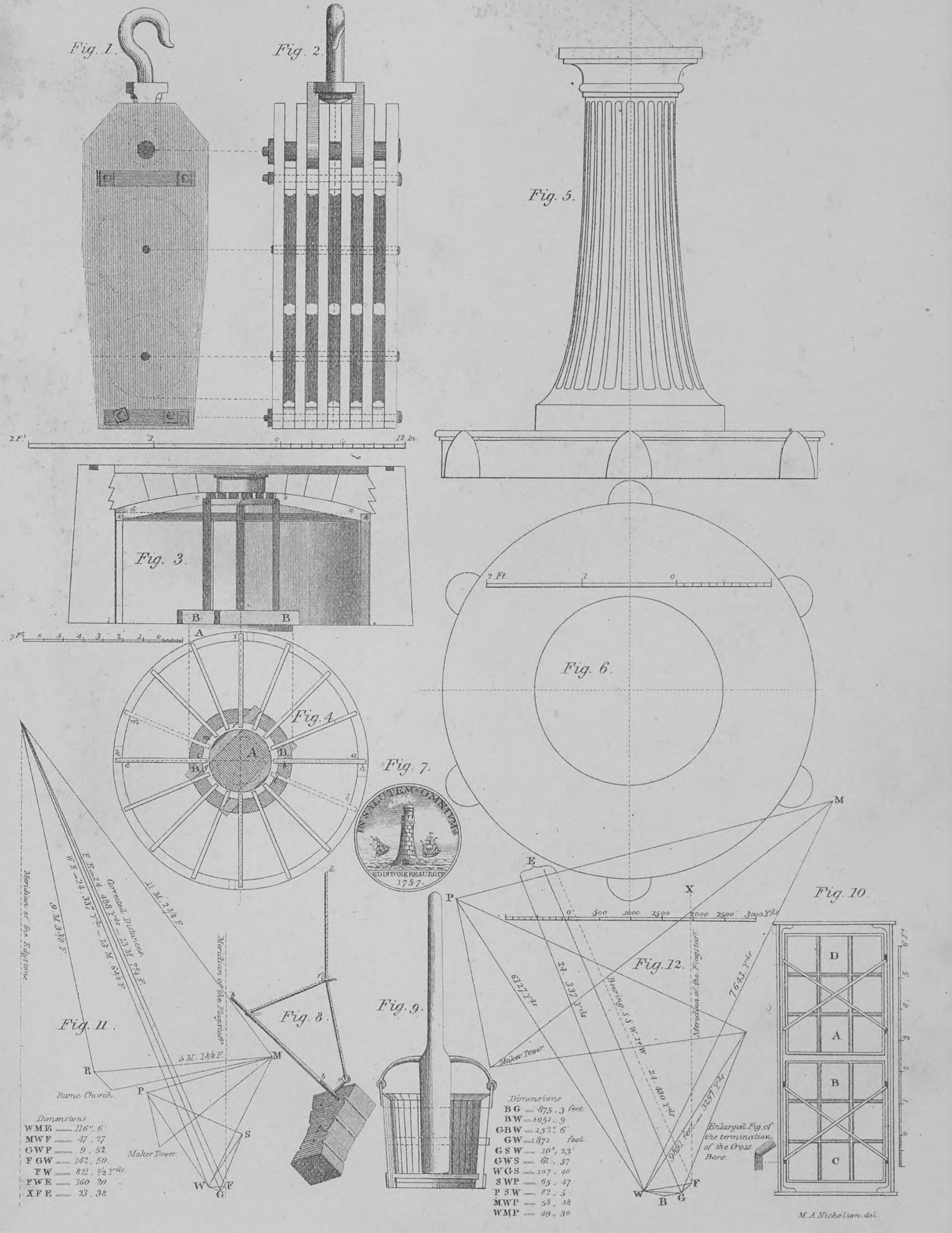
LIGHT HOUSE.

Plan and description of the Work Yard and Mill Bay with its furniture and utensils.



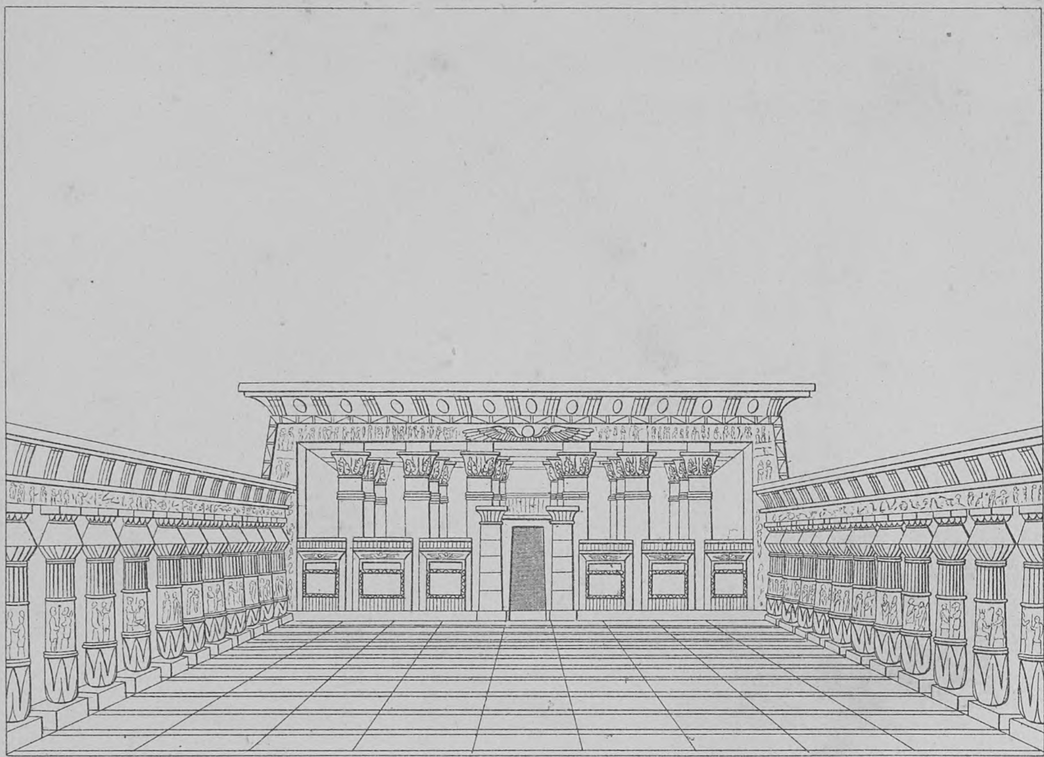
Drawn by P. Nicholson.

Engd. by R. Thew.

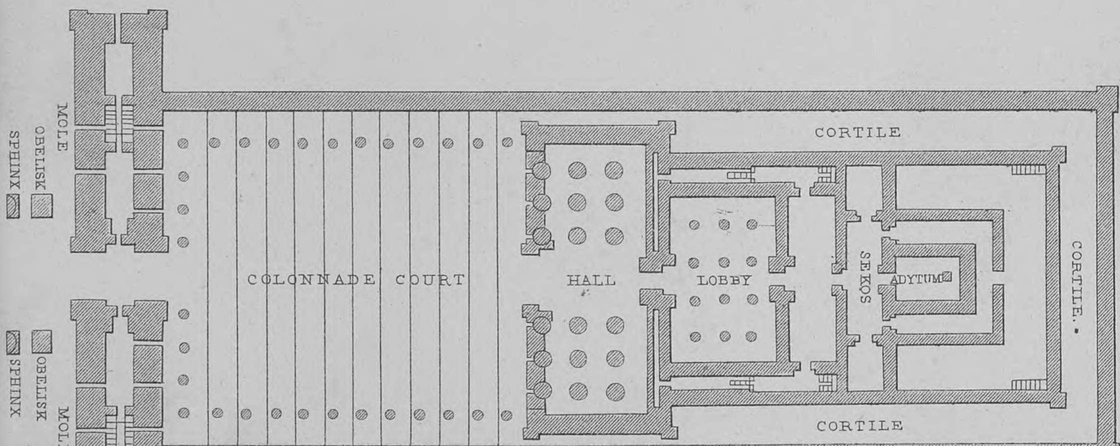


M. A. Nicholson. del.

PLAN AND INTERIOR COURT OF EGYPTIAN TEMPLE AT EDFOU.



COURT OF THE TEMPLE.



GENERAL PLAN.

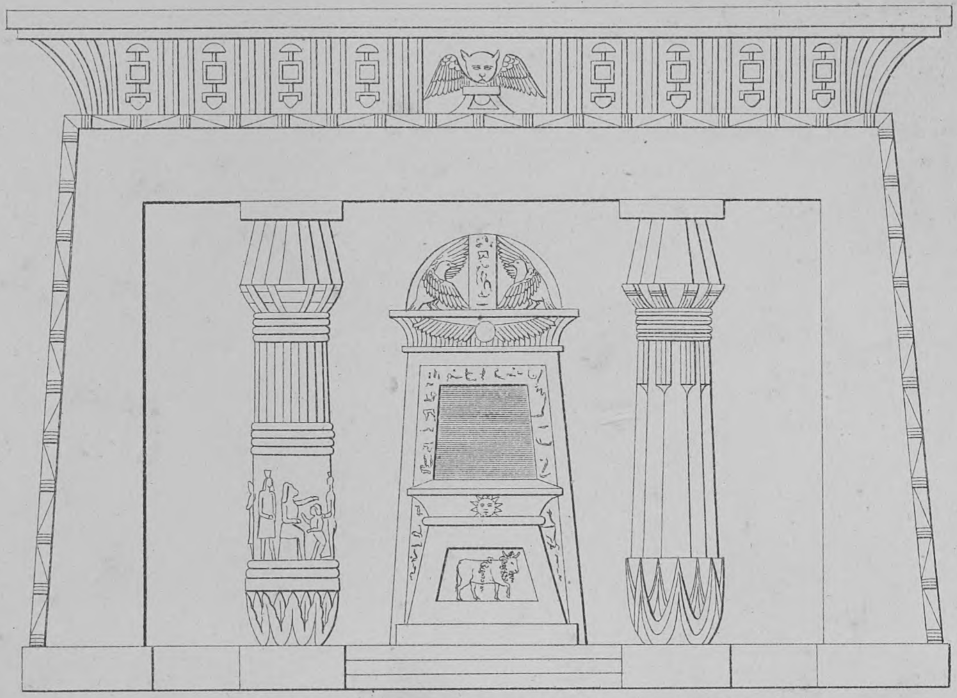
R. Brown Archt.

R Thew sc.

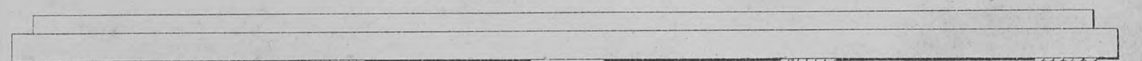
R. Brown Arch.

R. Thew Sc.

EGYPTIAN FACADES OF PORTICOS.



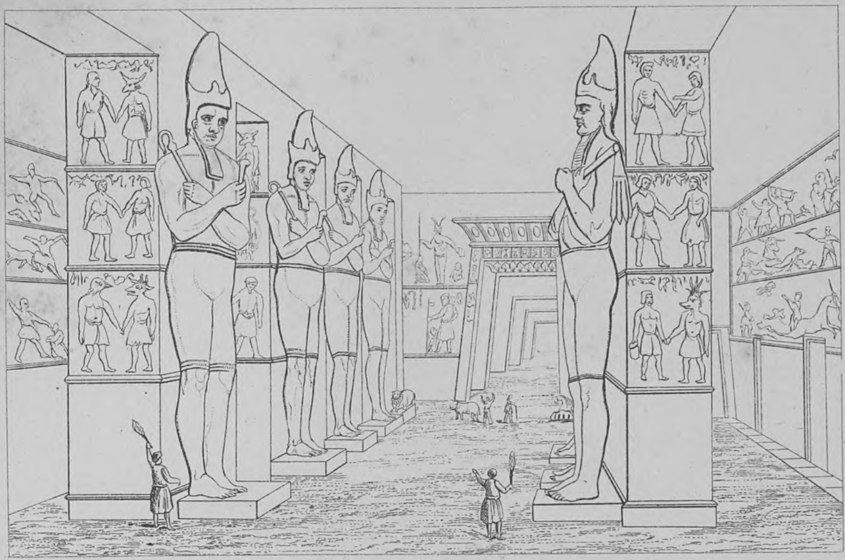
AN EGYPTIAN TEMPLE AND ALTAR OF OSIRIS



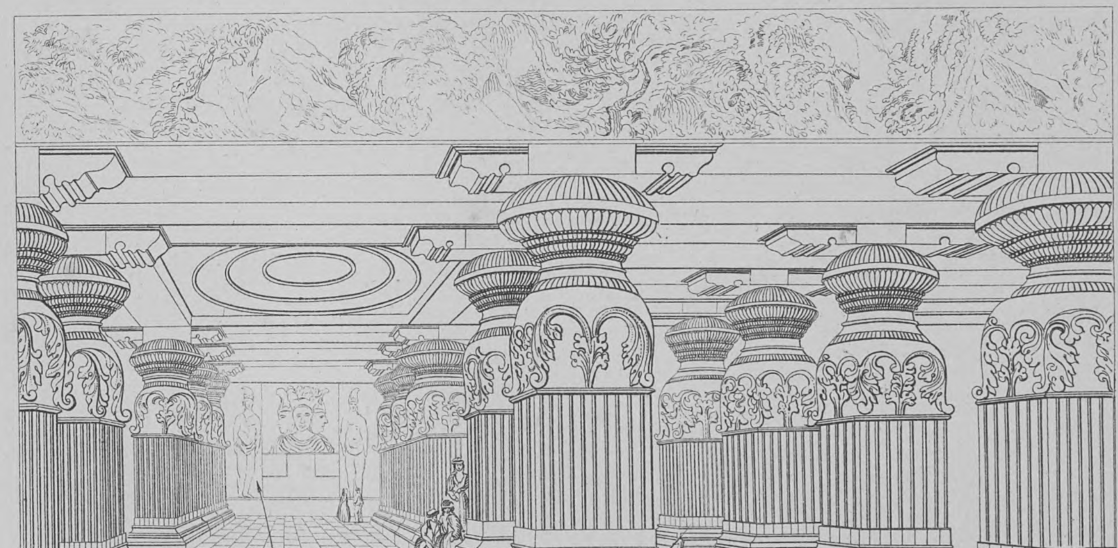
FACADE OF AN EGYPTIAN TEMPLE OF ISIS

R. Brown Archt. R. Thew sc.

EGYPTIAN INTERIOR OF A TEMPLE AT IBSAMBAL.



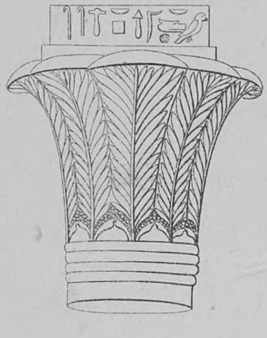
HINDOO INTERIOR OF A TEMPLE AT ELLORA.



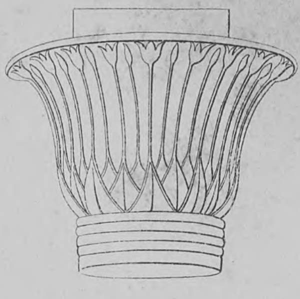
R. Brown. Archt. P. Thew. sc.

EXAMPLES OF EGYPTIAN CAPITALS OF COLUMNS

FROM TEMPLE OF KOURNOU

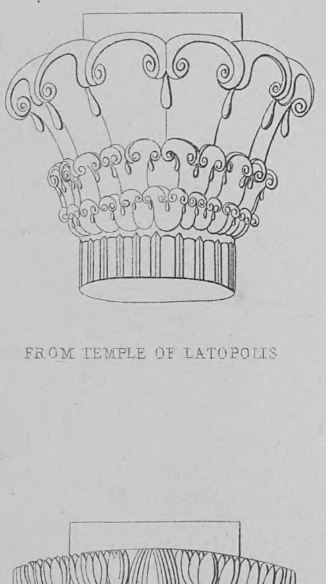


FROM TEMPLE OF APOLLONOPLIS

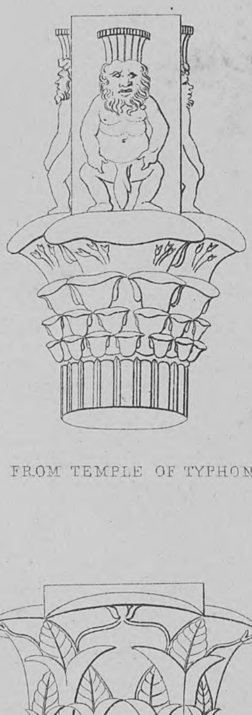


FROM TEMPLE OF APOLLONOPLIS

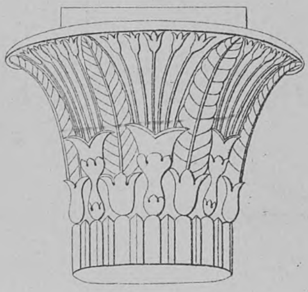
FROM TEMPLE OF TENTYRA



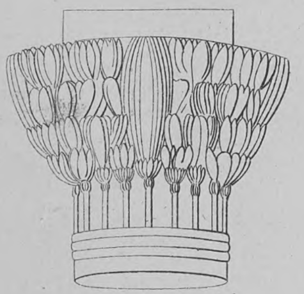
FROM TEMPLE OF LATOPOLIS



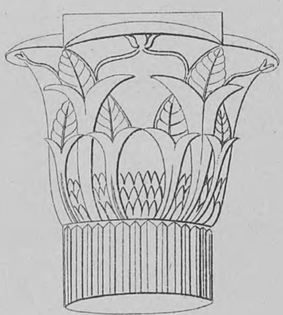
FROM TEMPLE OF TYPHON



FROM TEMPLE OF LATOPOLIS



FROM TEMPLE OF ESNE



FROM TEMPLE OF HERMONTIS

R. Brown, del.

R. Thew sc.

ELLIPSIS.

PLATE I.

Fig. 1.

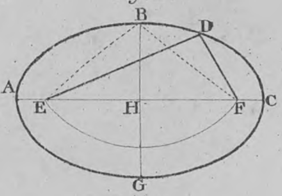


Fig. 2.

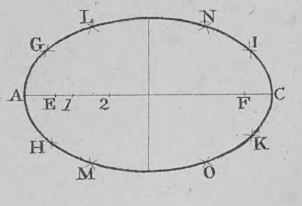


Fig. 3.

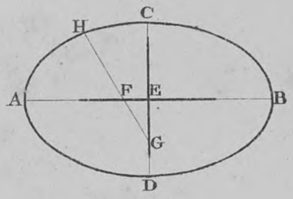


Fig. 4.

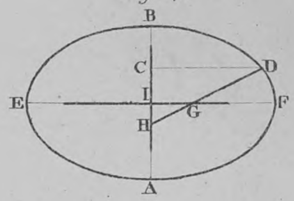


Fig. 7. No. 2.

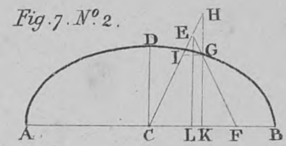


Fig. 5.

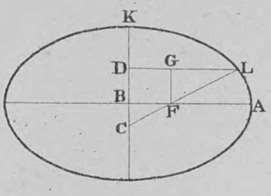


Fig. 6.

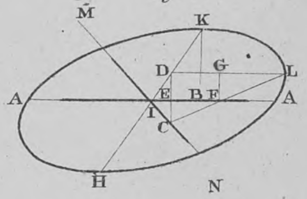


Fig. 7. No. 1.

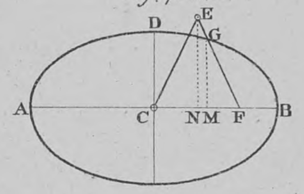


Fig. 8.

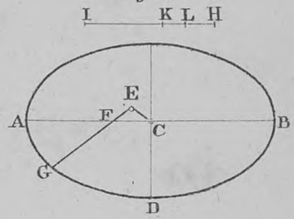


Fig. 9.

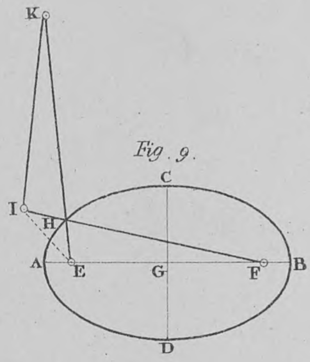


Fig. 10.

Fig. 10.

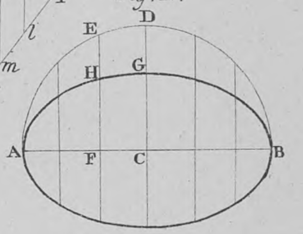


Fig. 11.

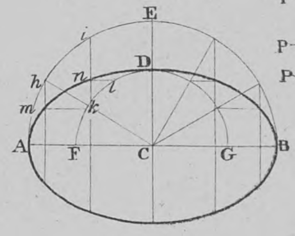


Fig. 12.

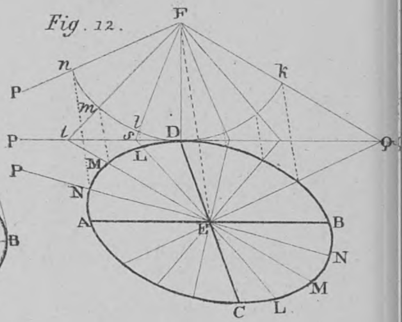
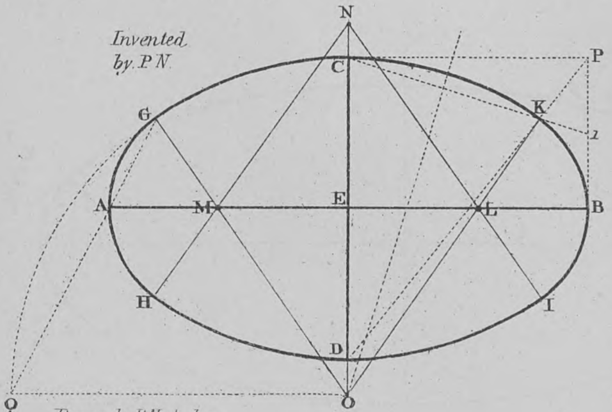


Fig. 13.

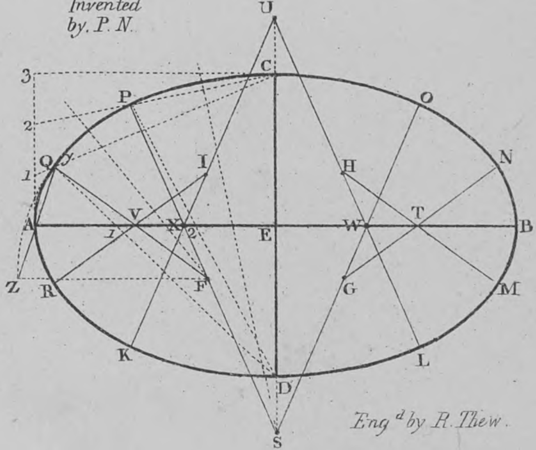
Invented by P.N.



Drawn by P. Nicholson.

Fig. 14.

Invented by P. N.



Eng.[d] by R. Thew.

ELLIPSIS.

PLATE II.

Fig. 15

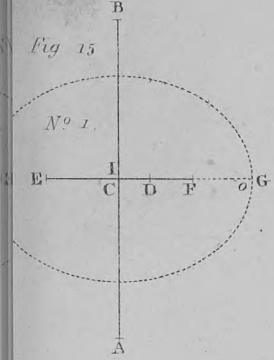


Fig. 15

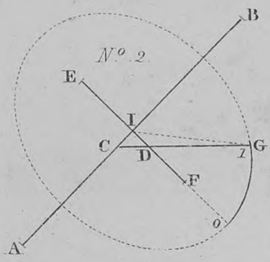


Fig. 15.

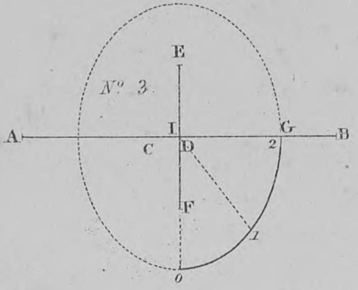


Fig. 15

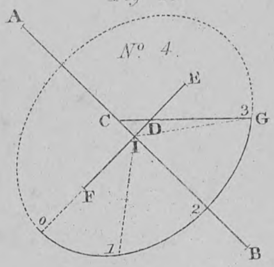


Fig. 15.

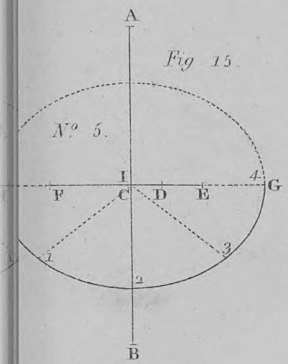


Fig. 15.

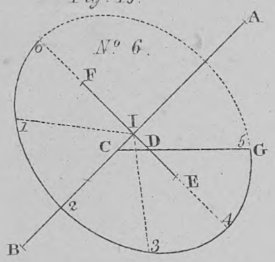


Fig. 15

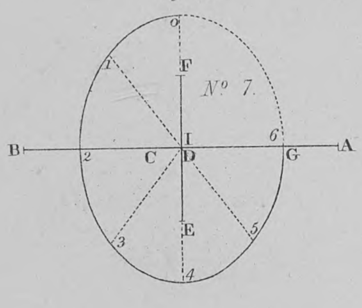


Fig. 15.

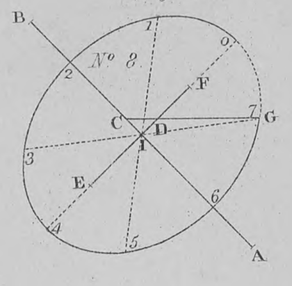


Fig. 16.

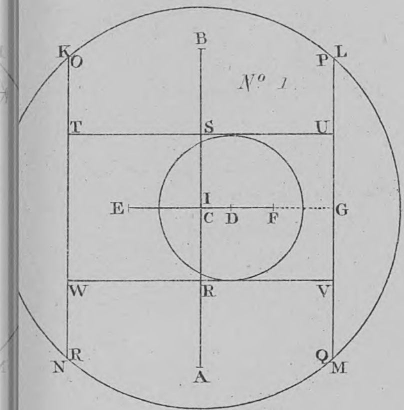


Fig. 16.

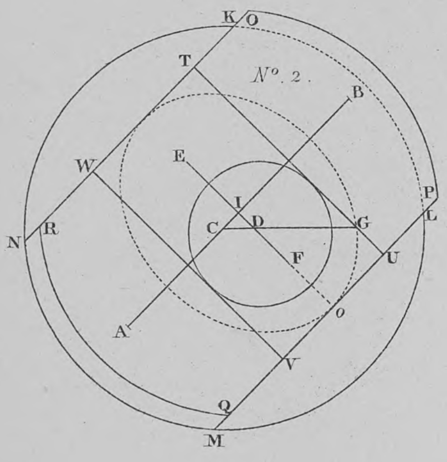


Fig. 16.

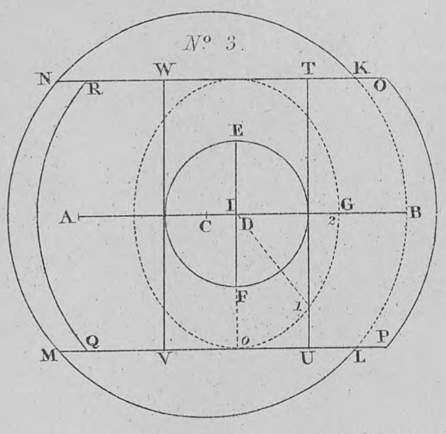
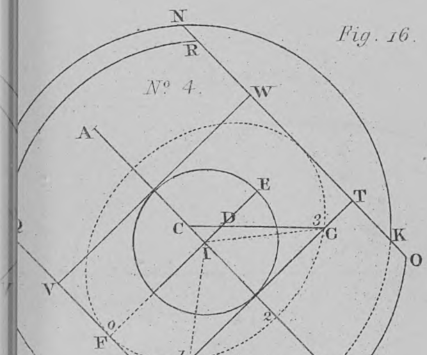
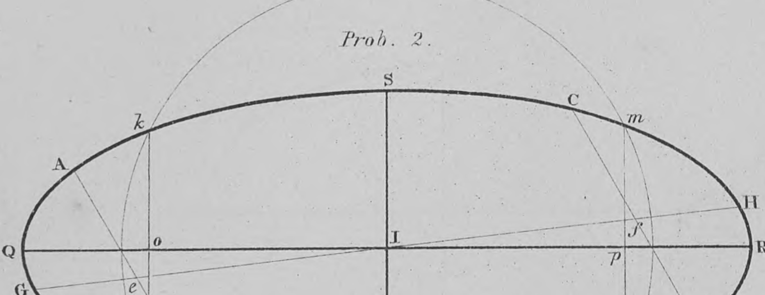


Fig. 16.



Prob. 2.



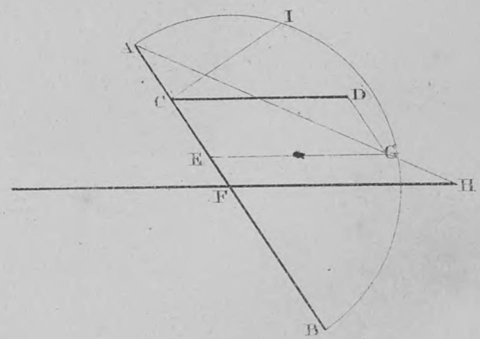
The first 12 diagrams.
Invented by P. Nicholson.

Engᵈ by R. Thew.

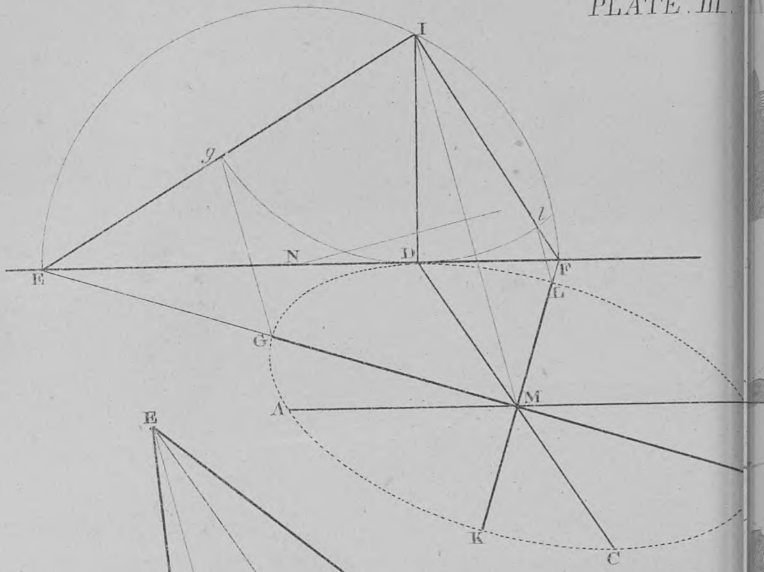
ELLIPSIS.

PLATE. III.

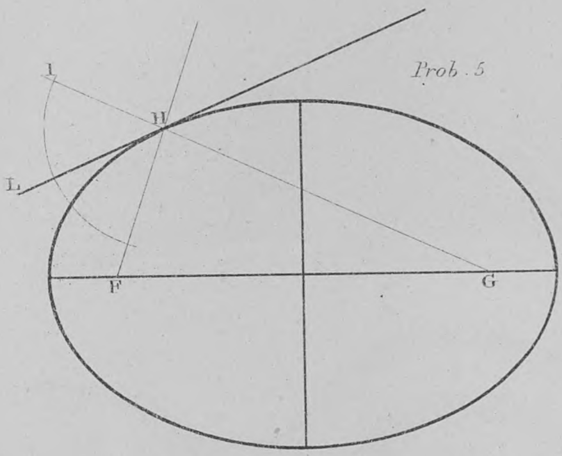
Prob. 3.



Prob 4.



Prob. 5



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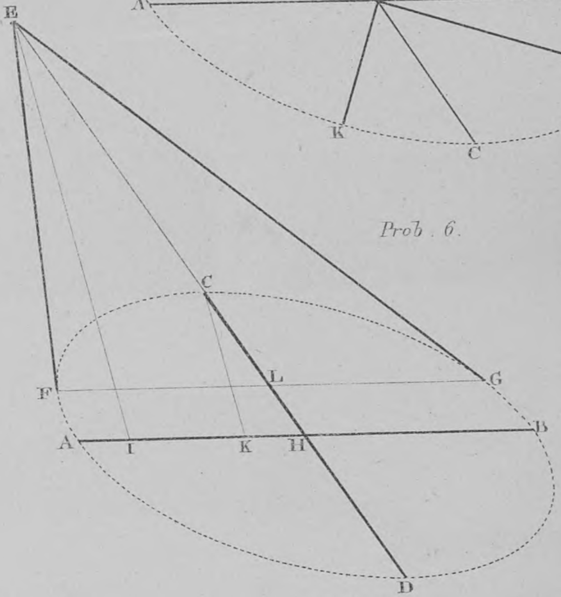
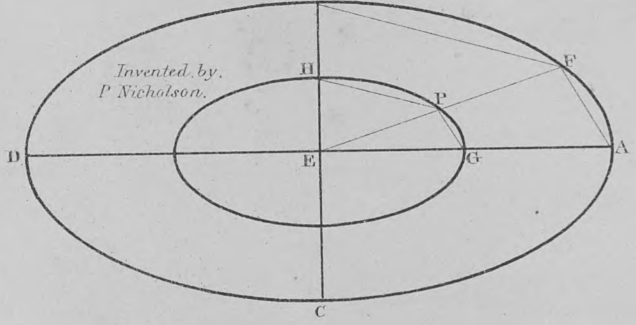
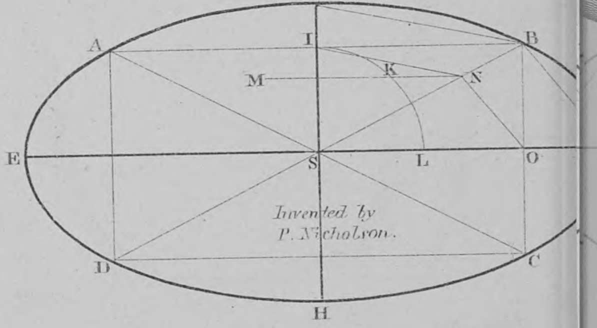


Prob. 7.



Prob. 8.



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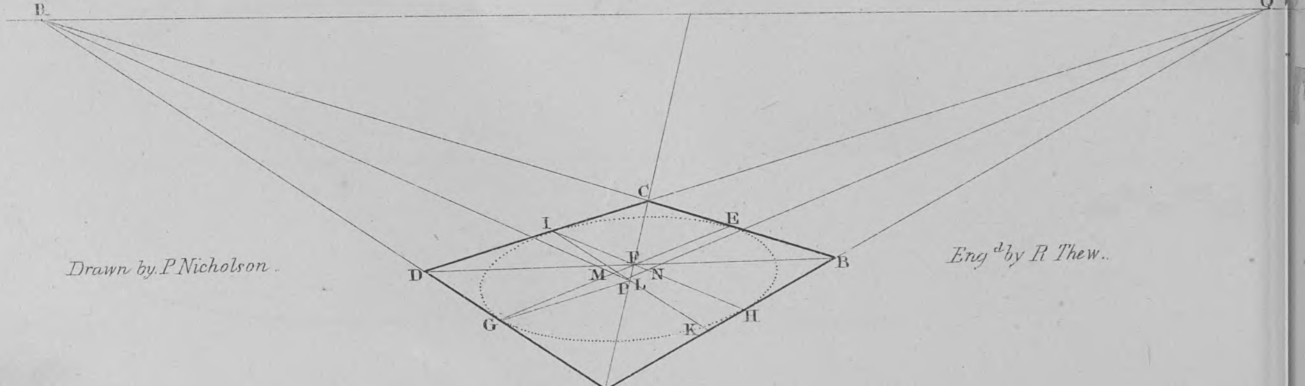

Drawn by P Nicholson.

Eng^d by R Thew.

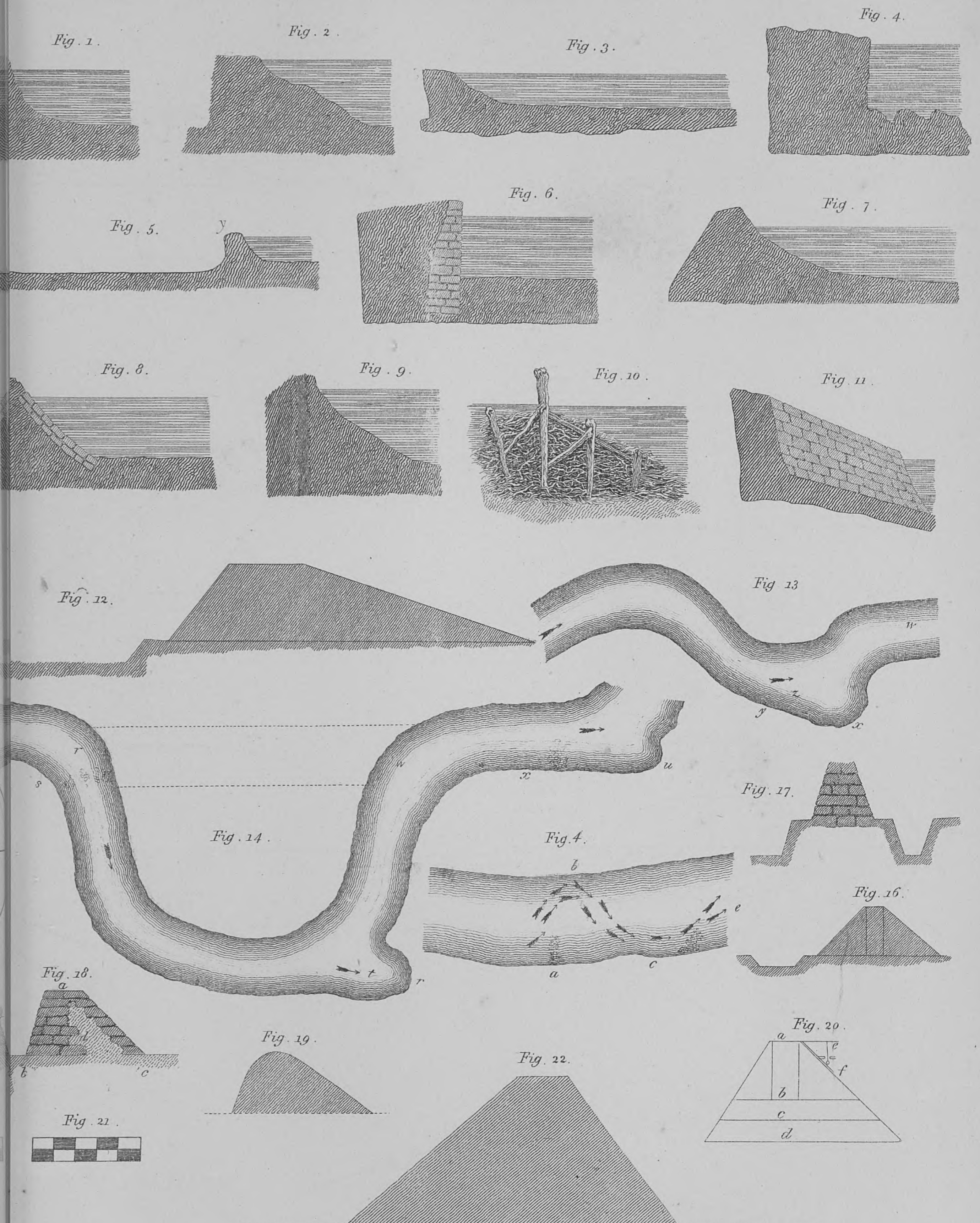
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
y
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 11.
Fig. 12.
Fig 13
w
z
y
x
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s
w
x
u
Fig. 14.
t
r
Fig. 4.
b
e
a
c
Fig. 17.
Fig. 16.
Fig. 18.
a
d
b
c
Fig. 19.
Fig. 22.
Fig. 20.
a
e
f
b
c
d
Fig. 21.
Eng^d by R. Thew.

ENVELOPES OF SOLIDS.

PLATE I.

Fig. 1.

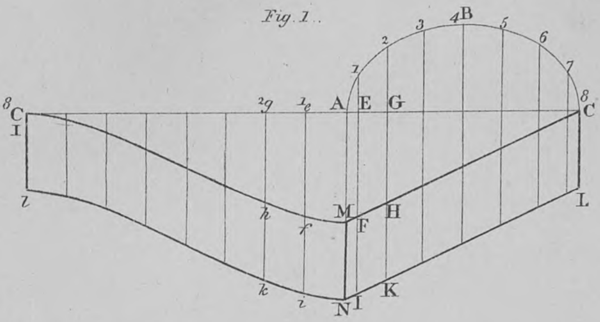


Fig. 2.

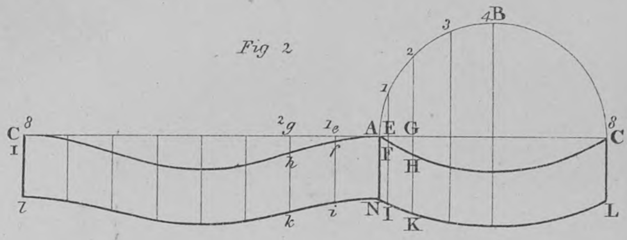


Fig. 3.

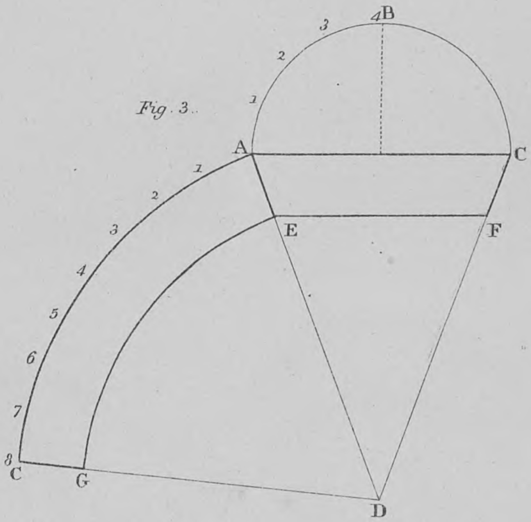


Fig. 4.

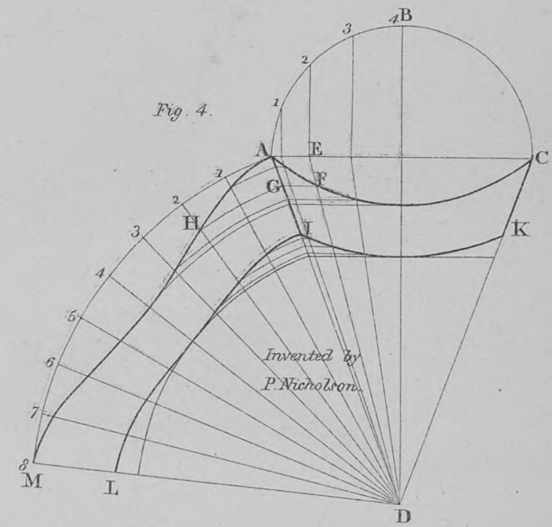


Fig. 5.

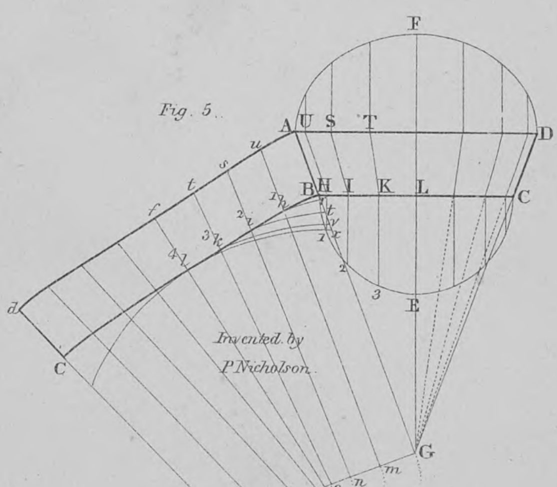
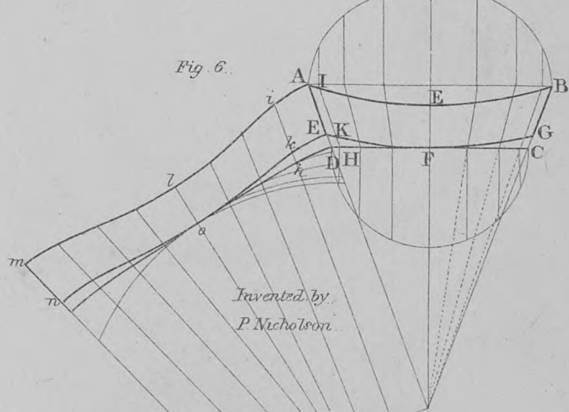


Fig. 6.



Drawn by M.A. Nicholson

Eng.d by R. Thew.

ENVELOPE.

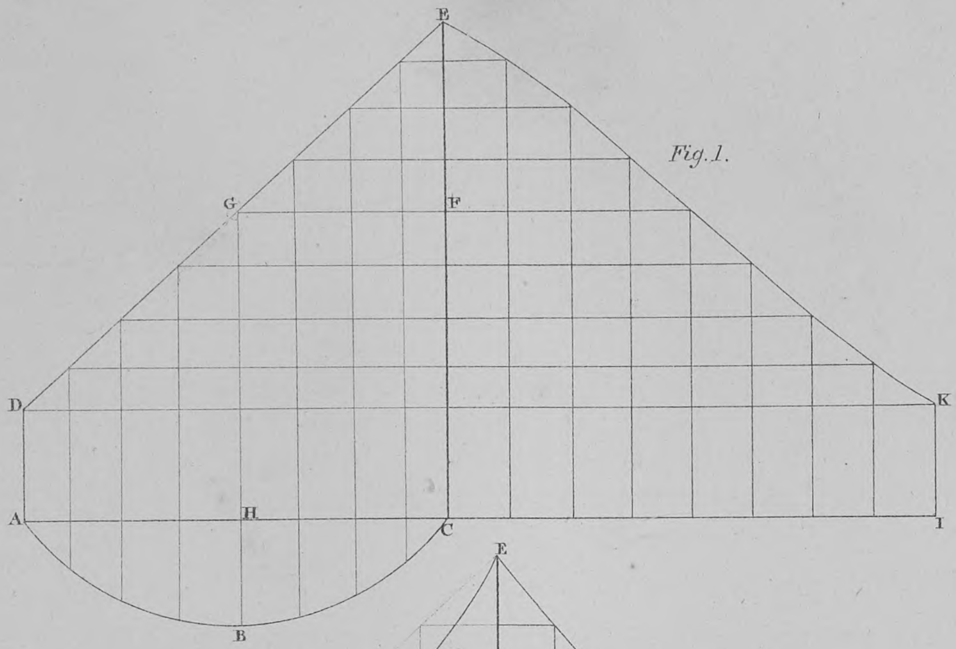


Fig. 1.

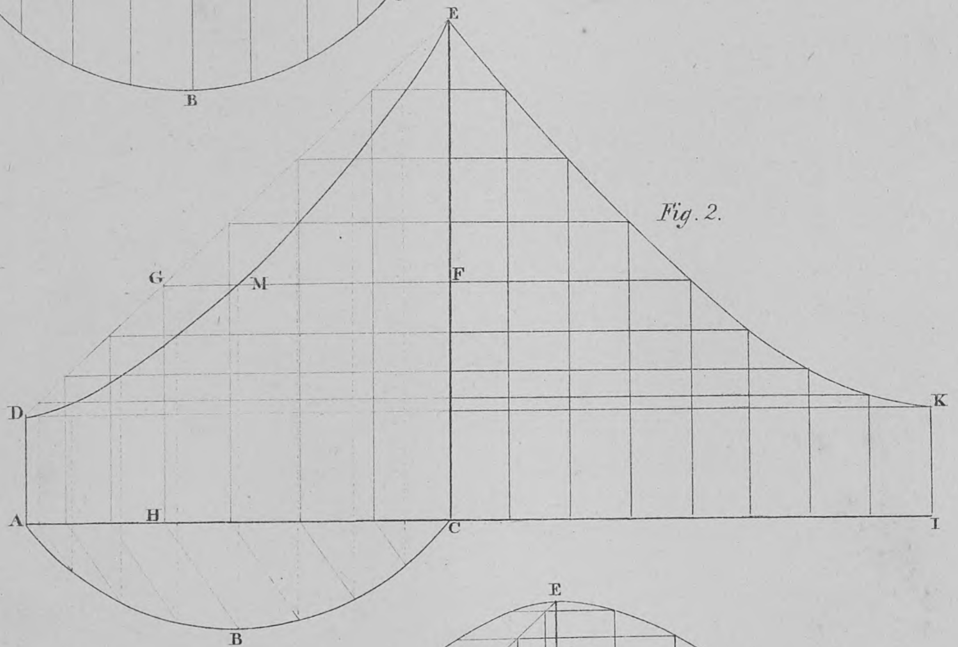


Fig. 2.

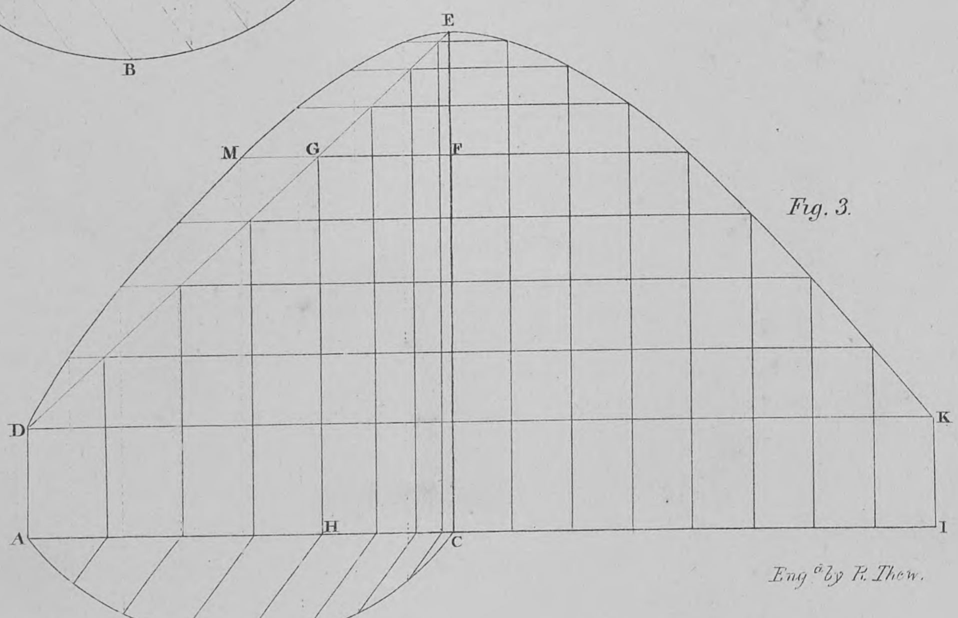


Fig. 3.

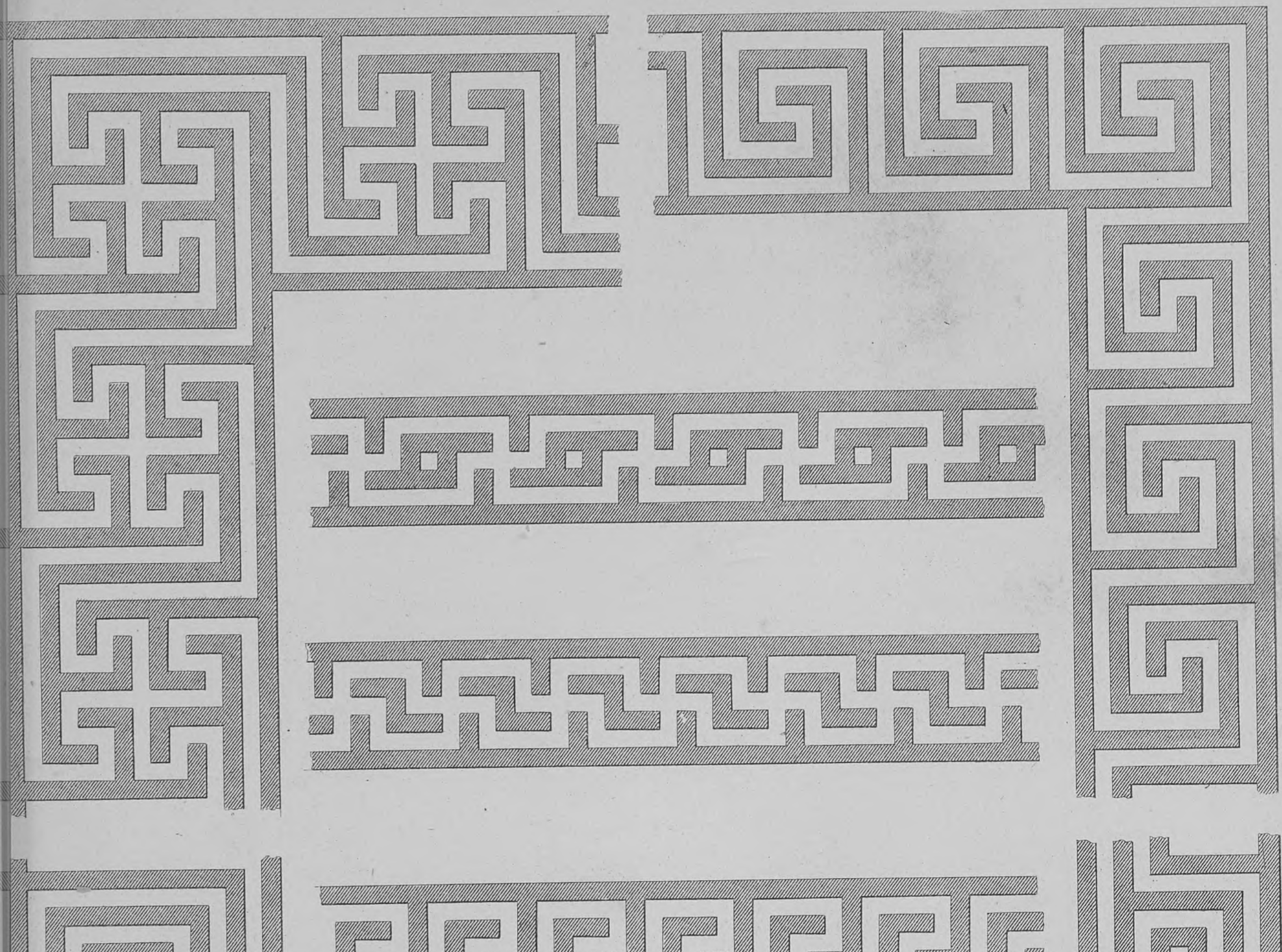
Drawn by P. Nicholson.

Engd by R. Thew.

A. Gilbert, Archt. del.

R. Thew Sc.

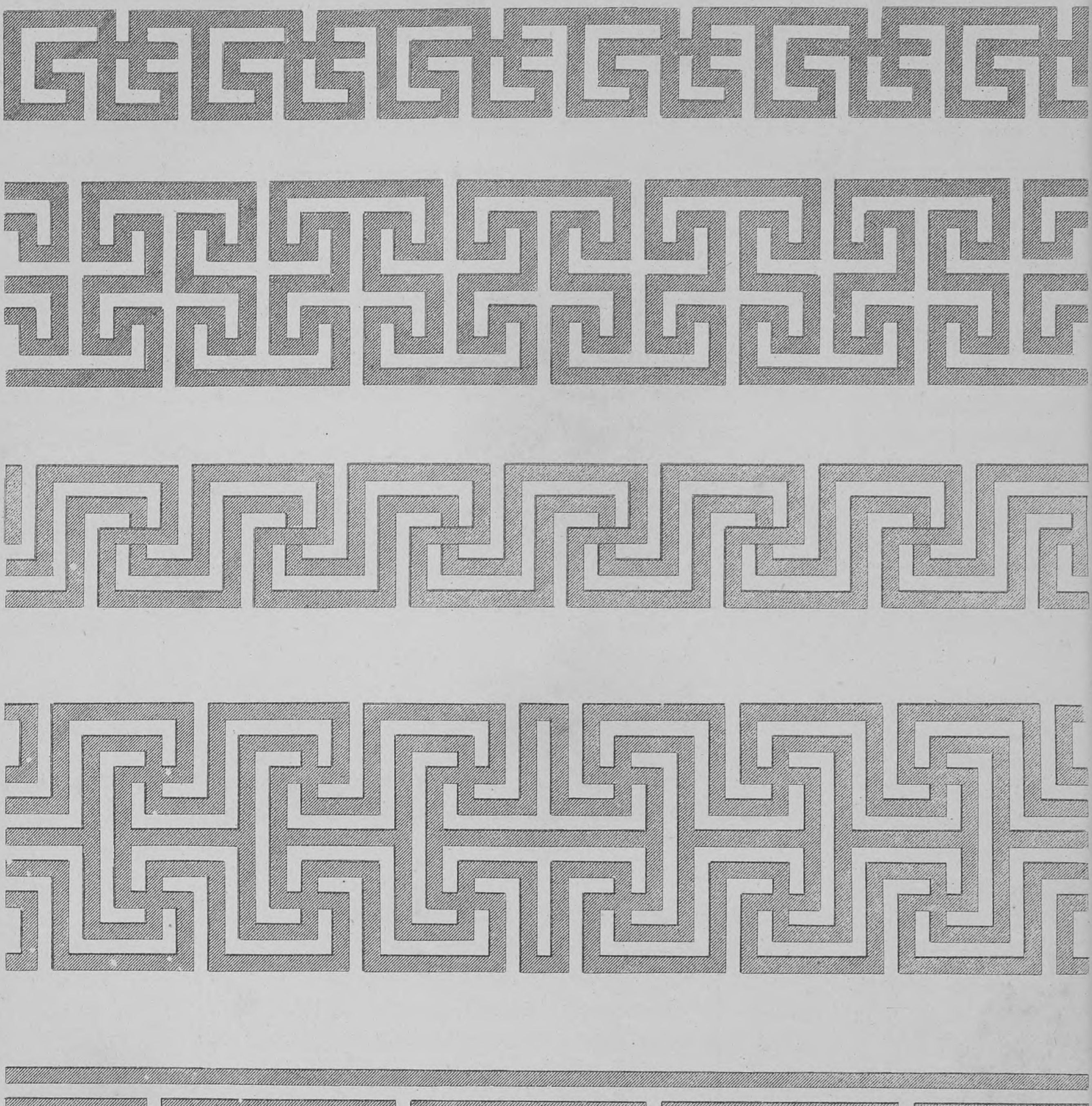
Nº 1. Fan-tracery Vaulting.
Nº 2. Fenestella.
Nº 3. Finial.
Nº 4. Flying Buttress.
Nº 5. Font. Nº 6. Frieze.
Nº 7. Gablet.
Nº 8. Gargoyle.
Nº 9. Guilloche.
Nº 10. Hammer beam.
Nº 11. Hip knob.
Nº 12. Hypæthral Temple.
Nº 13. Hypotrachelium.



by P. Nicholson.

Eng^d. by R. Thew.

FRETS.



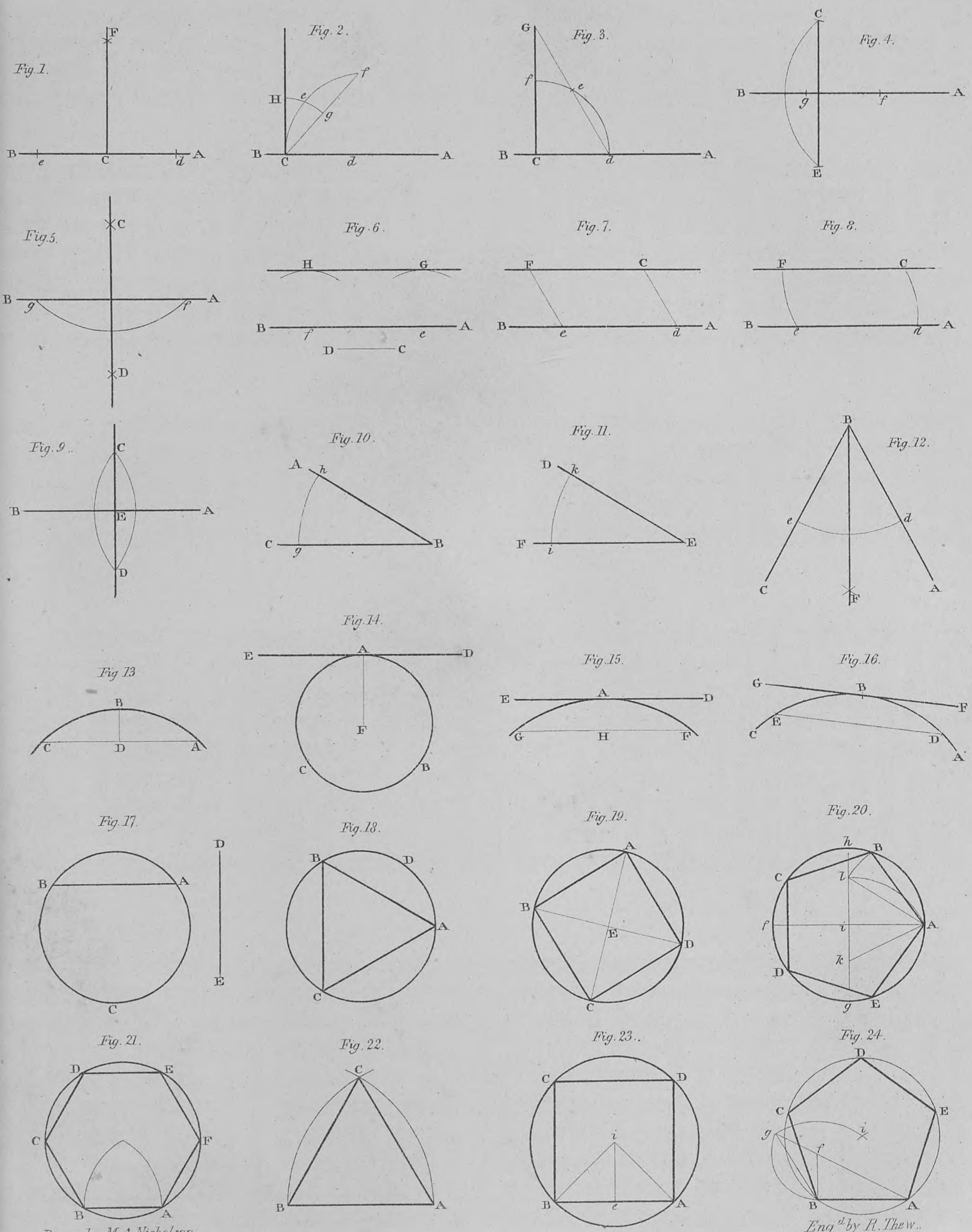
Drawn by P. Nicholson

Eng^d by R. Thew.

GEOMETRY.

PRACTICAL.

PLATE. I.

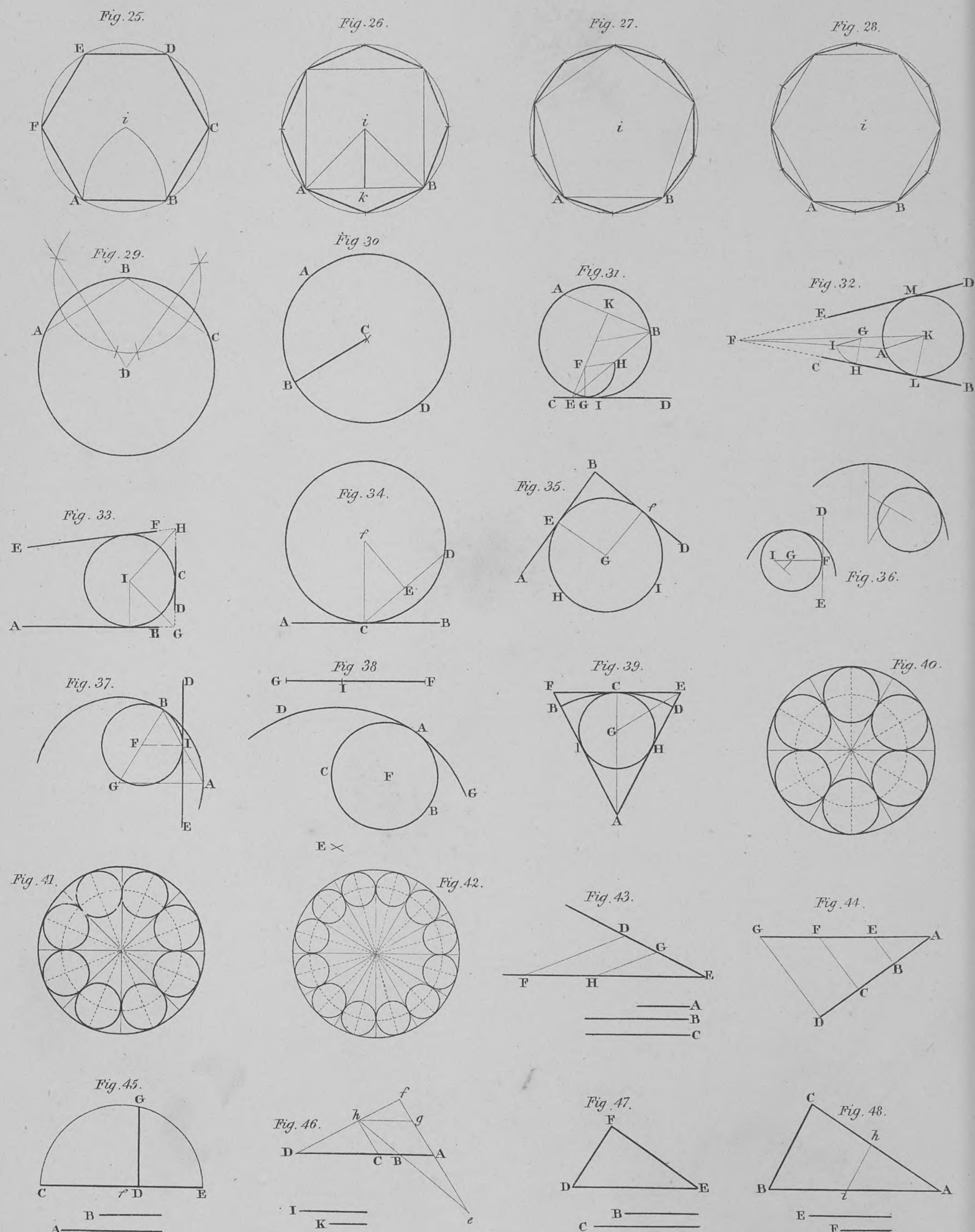


Drawn by M.A Nicholson.

Eng^d by R. Thew.

GEOMETRY.
PRACTICAL.

PLATE II.



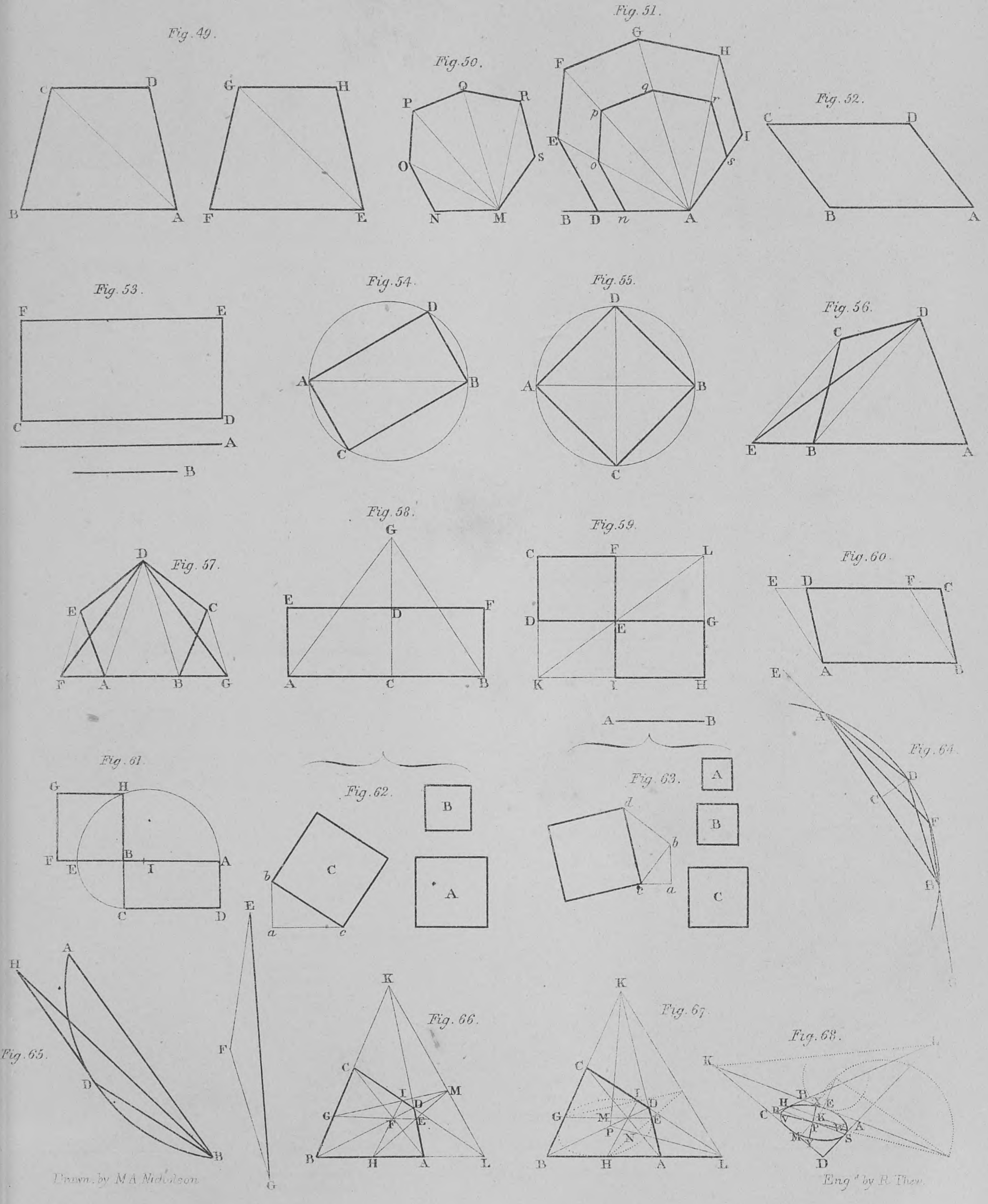
Drawn by M.A. Nicholson.

Engd by R. Thew.

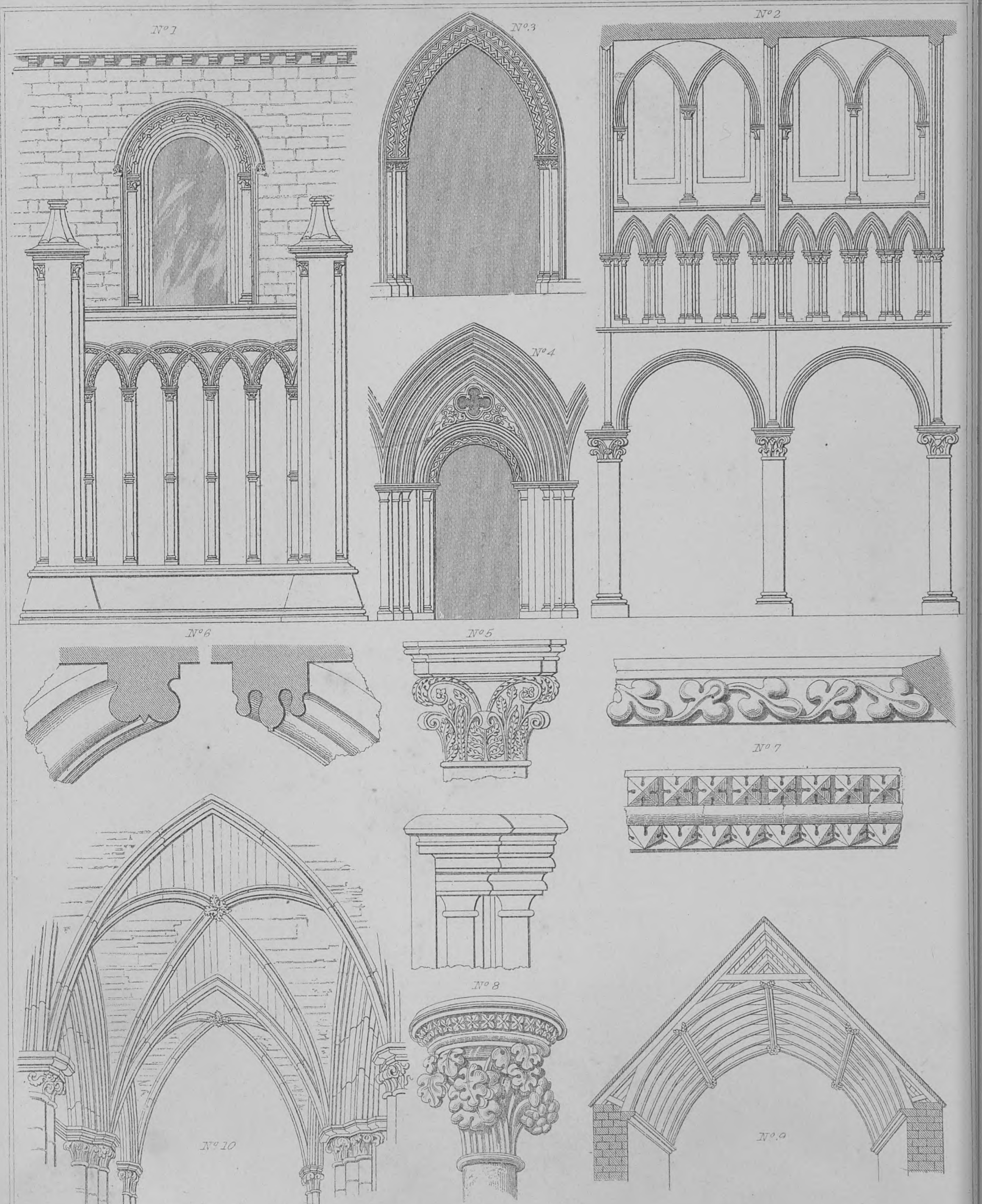
GEOMETRY

PRACTICAL

PLATE III.



SEMI-NORMAN AND EARLY ENGLISH EXAMPLES.



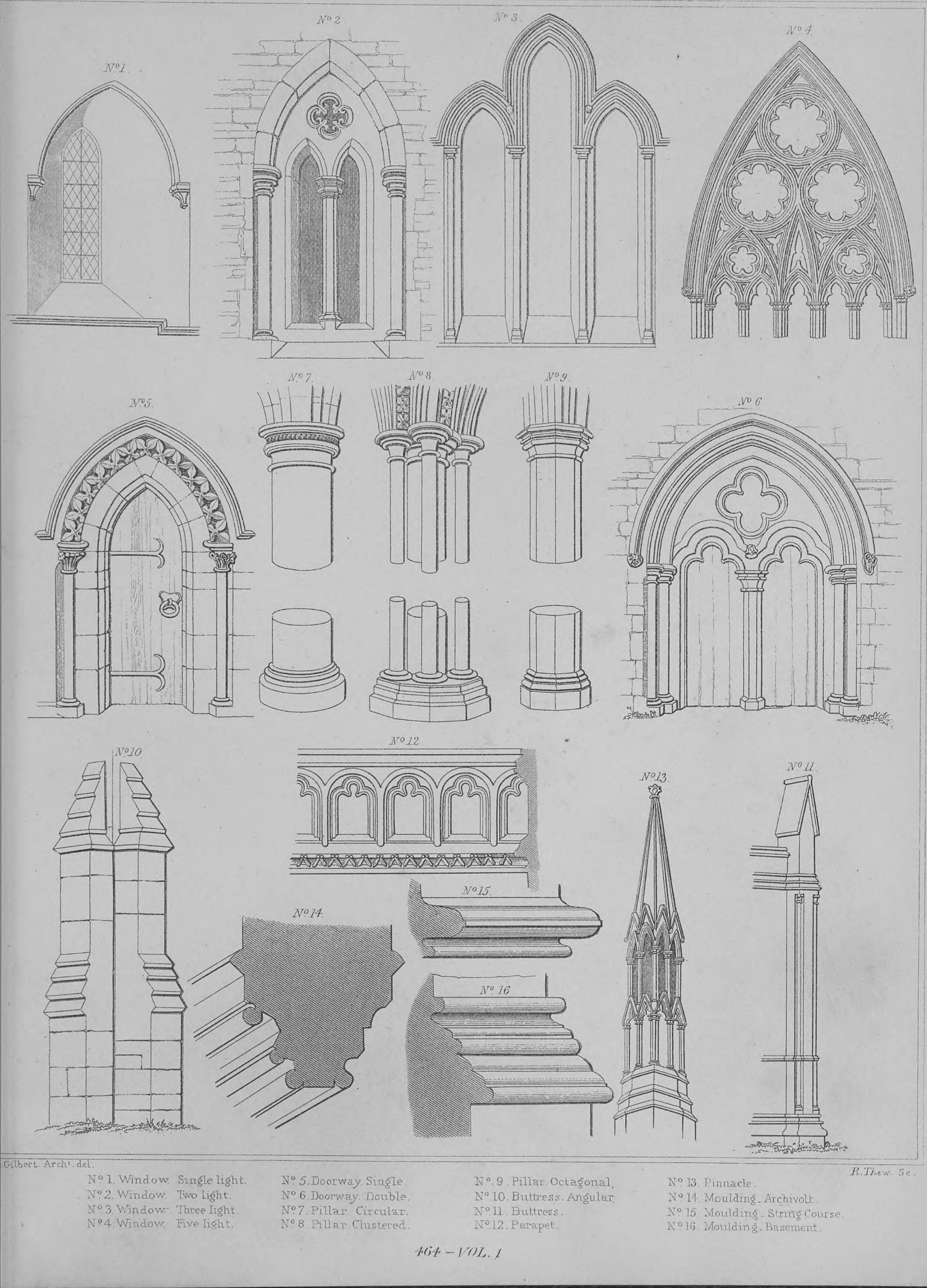
A. Gilbert, Archt. del. J. C. Buttre, sc.

SEMI-NORMAN

No 1. One division of North side of St. Joseph of Arimatheas Chapel adjoining West End of Glastonbury Abbey.
No 2. Canterbury Cathedral, Section of Compartment, Interior
No 3. Arch No 4. Door No 5. Capital

EARLY ENGLISH

No 6. Mouldings, Vaulting Ribs
No 7. Ditto Ornamented
No 8. Capitals
No 9. Timber Roof No 10. Stone Ditto



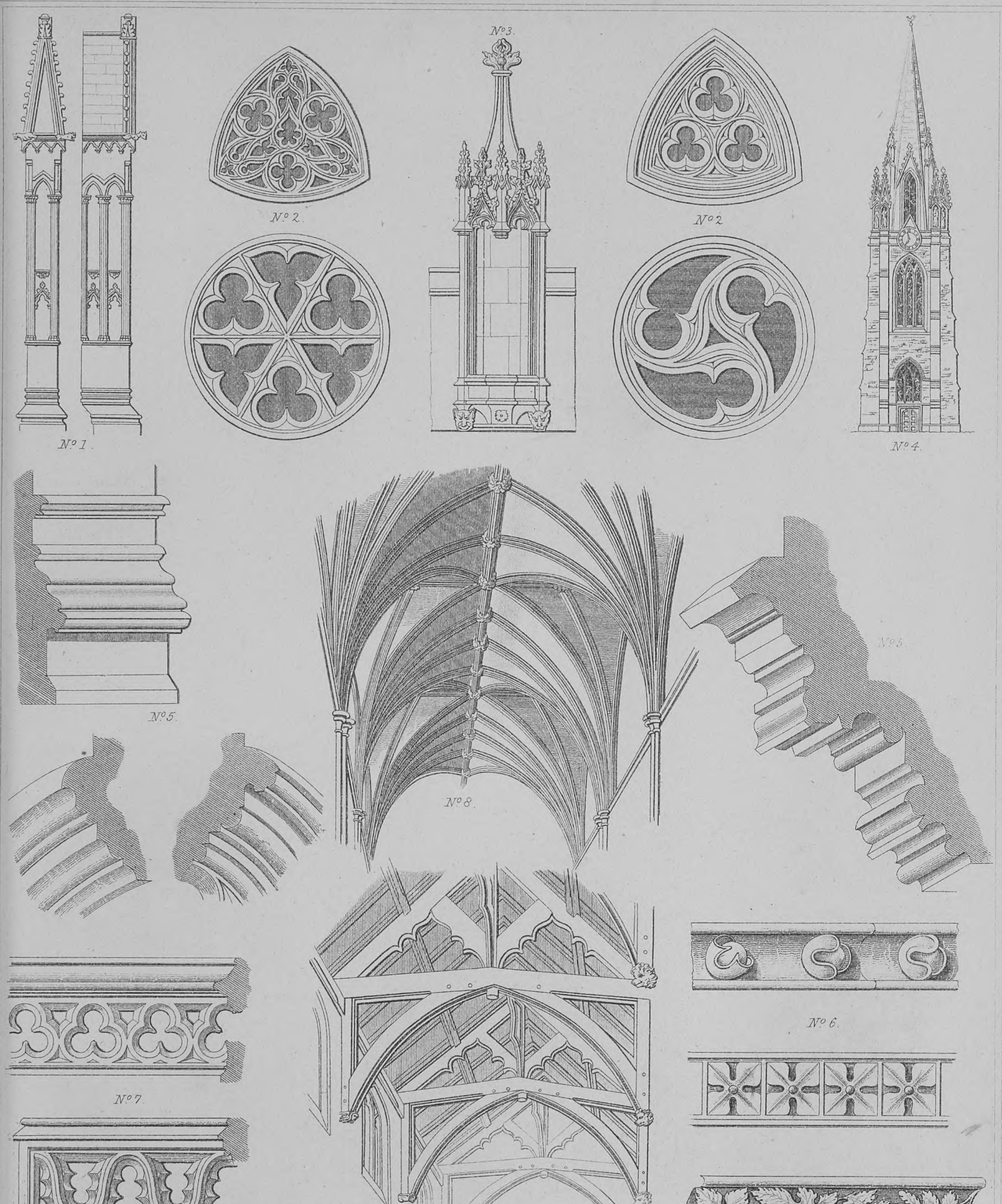
...Gilbert. Archt. del. R. Thew. Sc.

Nº 1. Window. Single light.	Nº 5. Doorway. Single.	Nº. 9. Pillar. Octagonal.	Nº 13. Pinnacle.
Nº 2. Window. Two light.	Nº 6. Doorway. Double.	Nº. 10. Buttress. Angular.	Nº 14. Moulding. Archivolt.
Nº 3. Window. Three light.	Nº 7. Pillar. Circular.	Nº 11. Buttress.	Nº 15. Moulding. String Course.
Nº 4. Window. Five light.	Nº 8. Pillar. Clustered.	Nº 12. Parapet.	Nº 16. Moulding. Basement.

A. Gilbert Archt. del.   J. C. Buttre sc.

Nº 1. Arch.
Nº 2. Shafts of Piers.
Nº 3. Capitals.
Nº 4. Bases.
Nº 5. Doorway.
Nº 6. Ditto. York Cathedral.
Nº 7. Ditto.
Nº 8. Window. Dunchurch, Warwickshire.
Nº 9. Window. St. Mary Magdalen Church, Warwickshire.
Nº 10. Ditto. St. Mary's, Oxford.
Nº 11. Ditto. Exeter Cathedral.
Nº 12. Ditto. West facade. Exeter Cathedral.

GOTHIC ARCHITECTURE — DECORATED EXAMPLES



A. Gilbert Archt. del.
B. Clew.

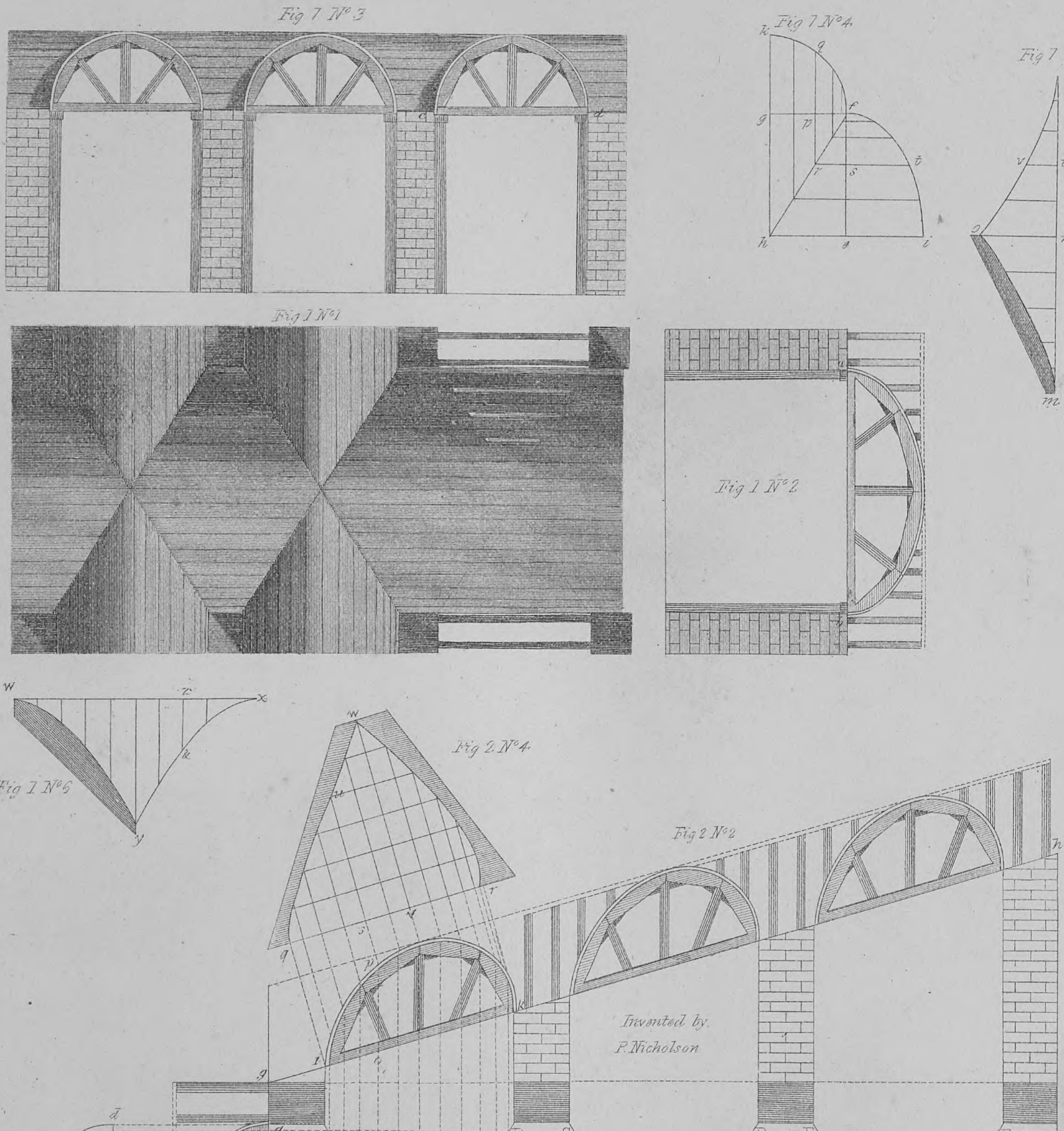
N° 1. Buttress.
N° 2. Windows.
N° 3. Niche.
N° 4. Tower & Spire.
N° 5. Mouldings.
N° 6. Ornamented Mouldings.
N° 7. Parapets.
N° 8. Vaulted Roof.
N° 9. Open Timber Roof.

A. Gilbert Archt. del. | J. C. Buttre.

Nº 1. Arch. | Nº 4. Doorway | Nº 7. Window.
Nº 2. Shaft and Base. | Nº 5. ditto. | Nº 8. ditto.
Nº 3. Capital. | Nº 6. Window. | Nº 9. ditto.

CENTERING FOR GROINS

PLATE I



Drawn by P. Nicholson.

Engd by R. Thew

RIBBING FOR GROINS, CEILINGS &c.

PLATE 1.

Fig. 1.

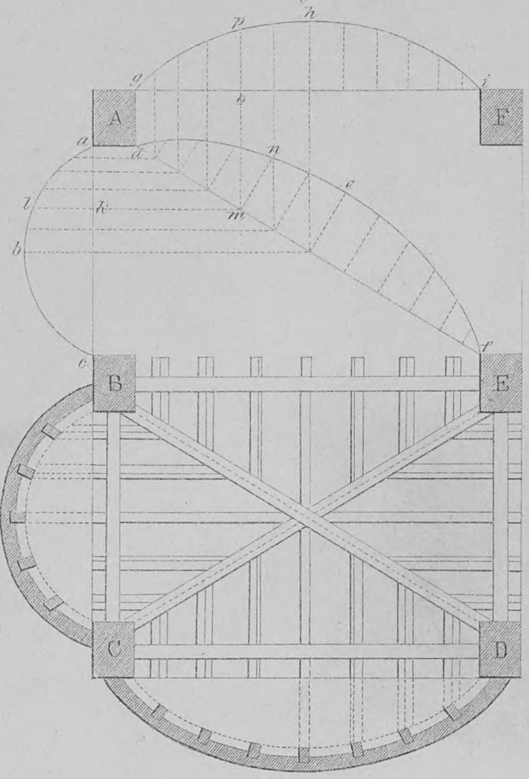


Fig. 2.

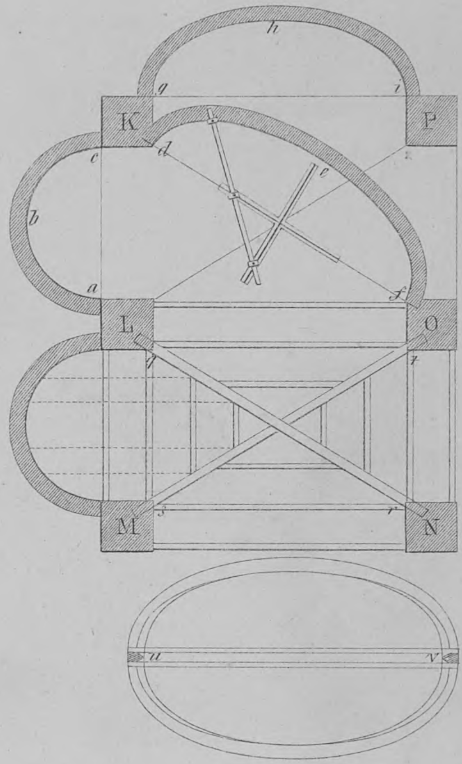


Fig. 3.

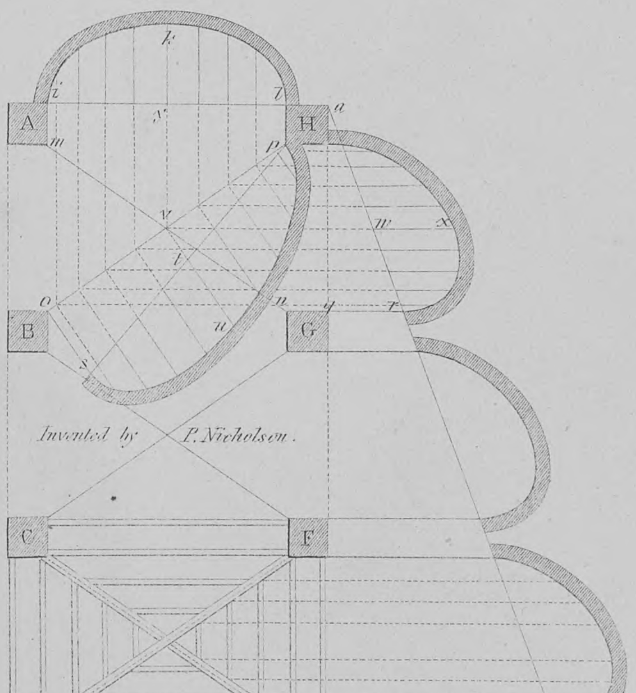
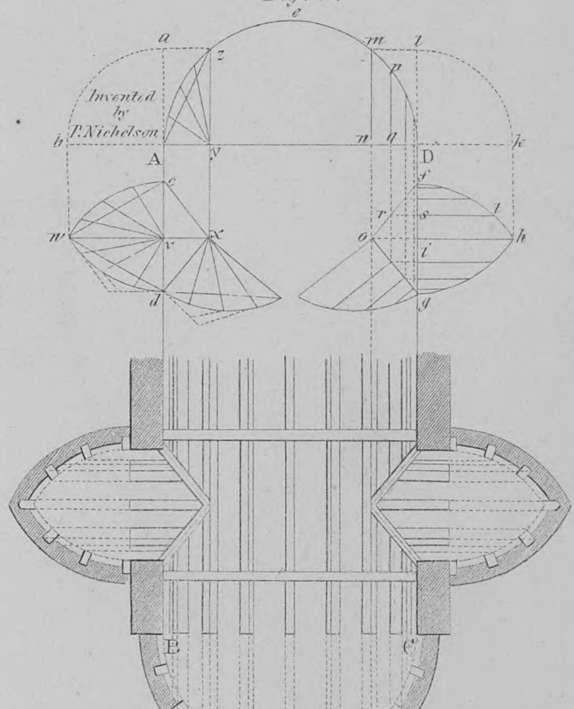
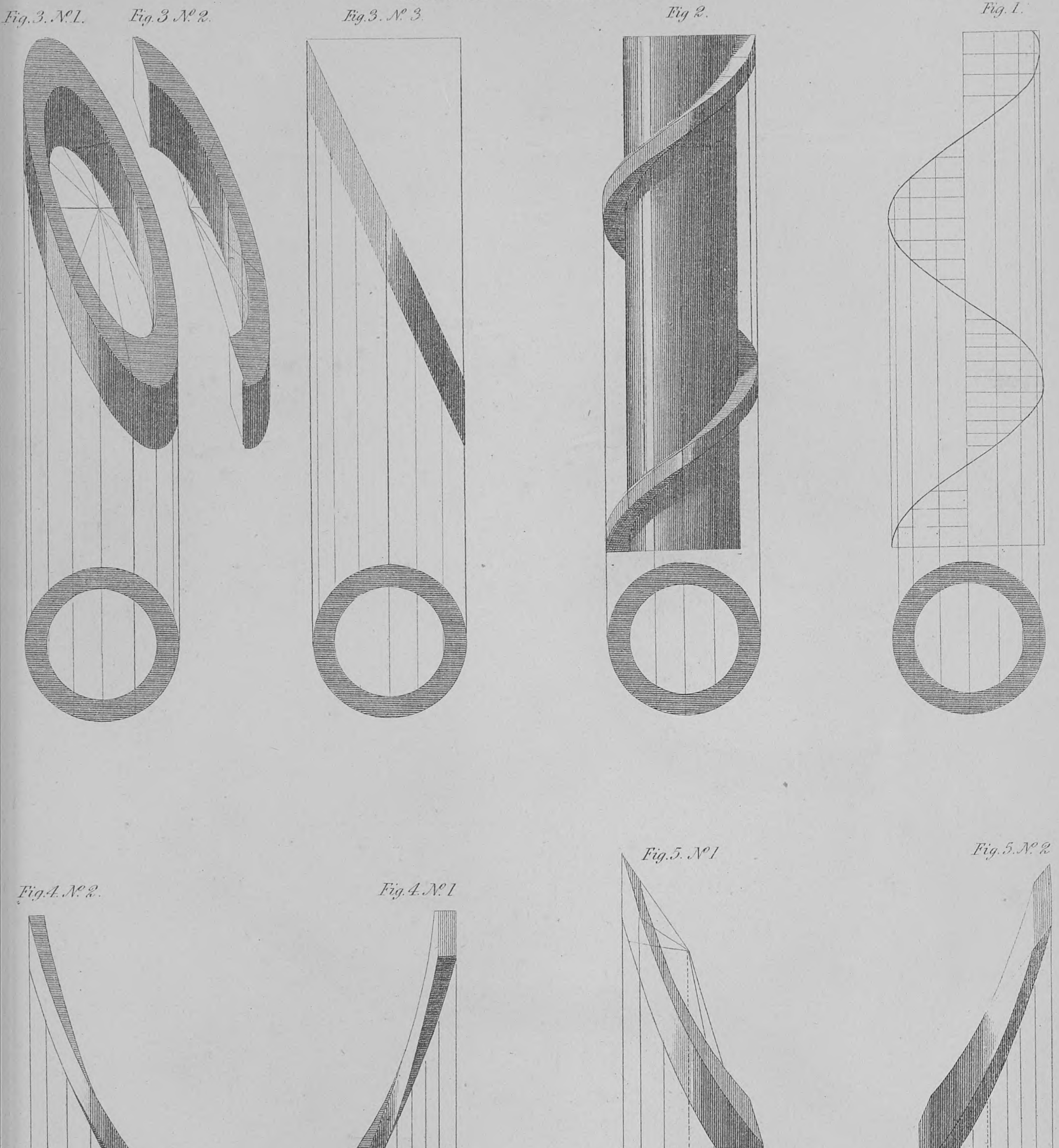


Fig. 4.

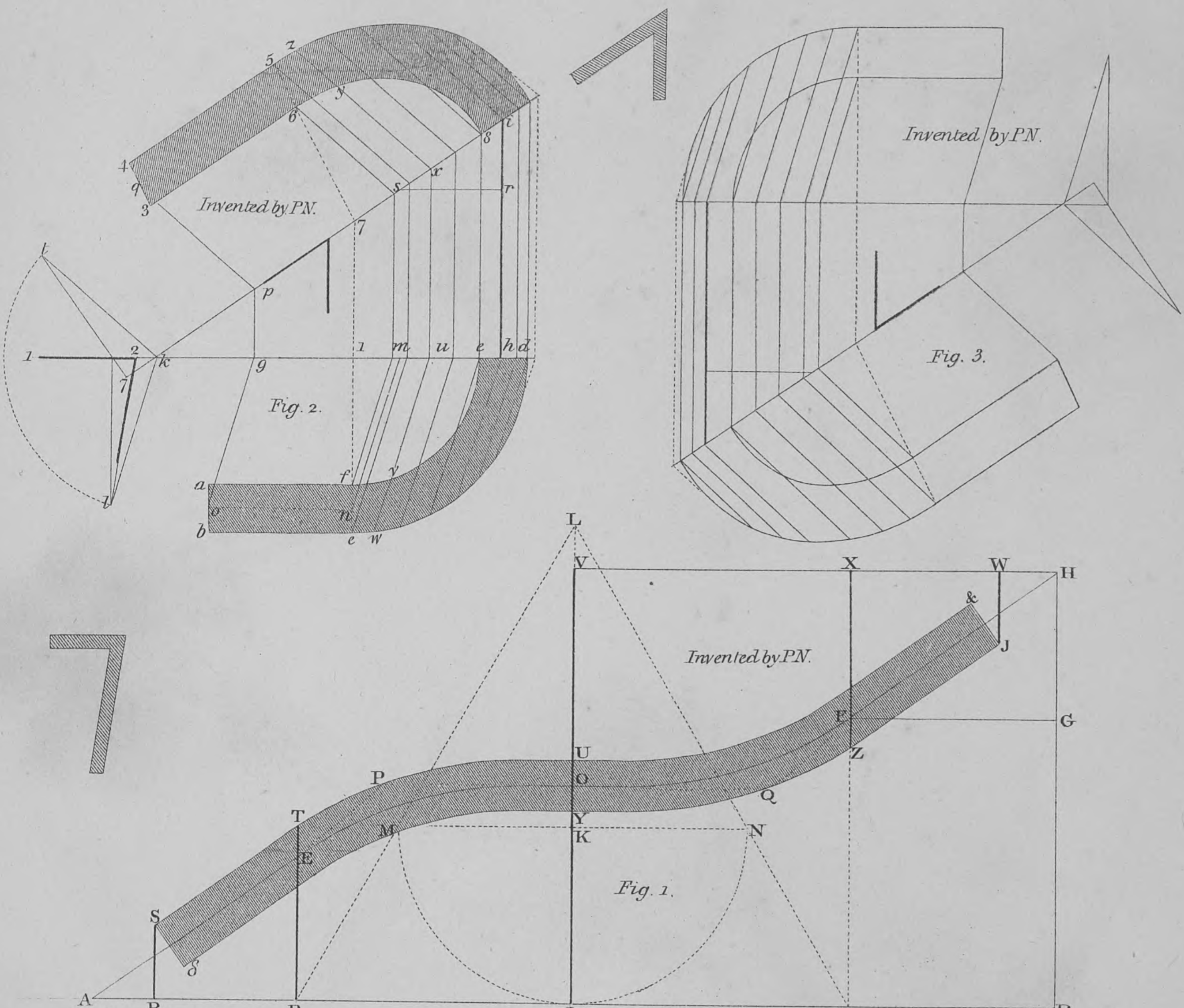


P. Nicholson.

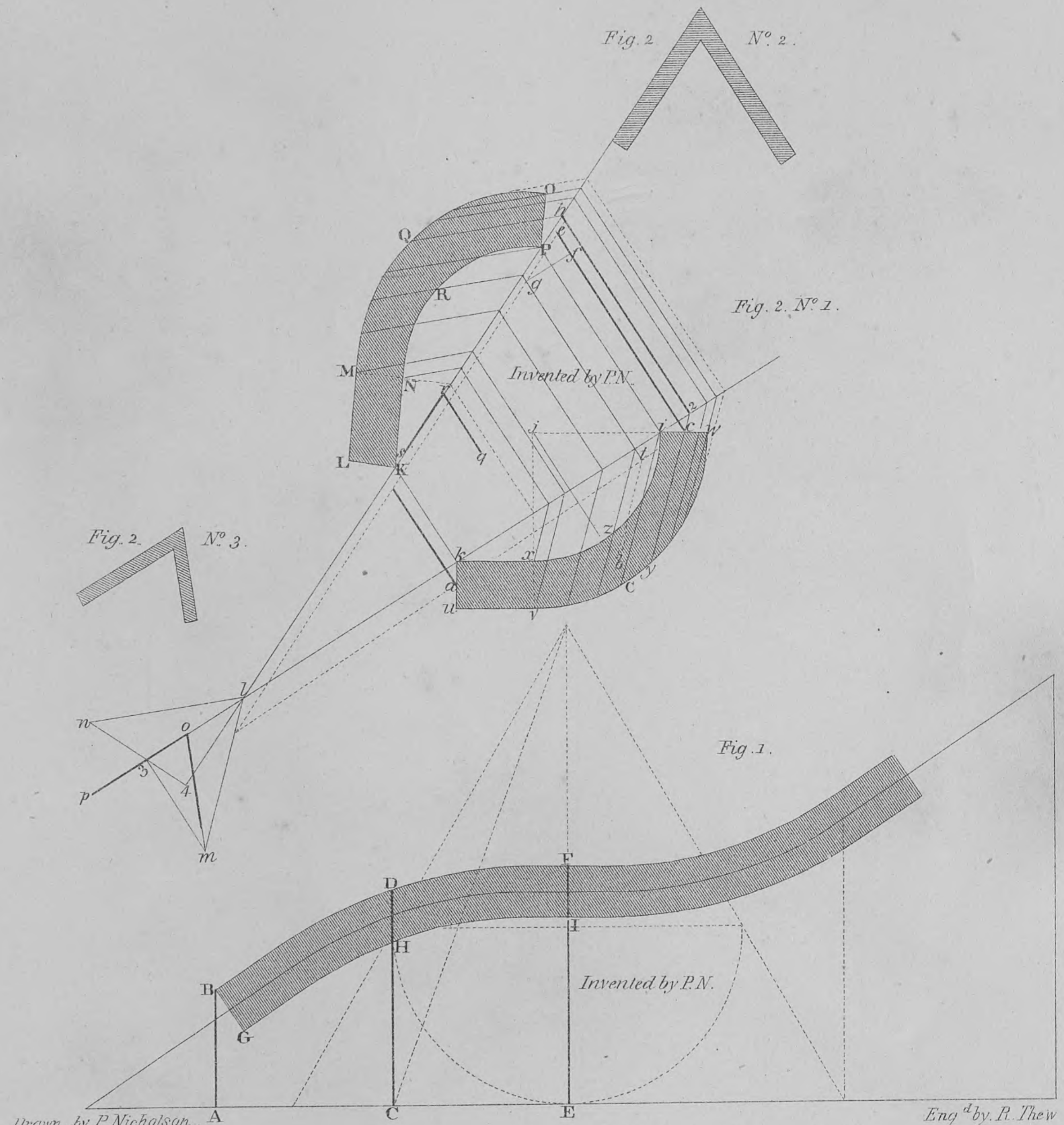
R. Thew.



Nicholson. del.



Drawn by P. Nicholson. Engd by R. Thew

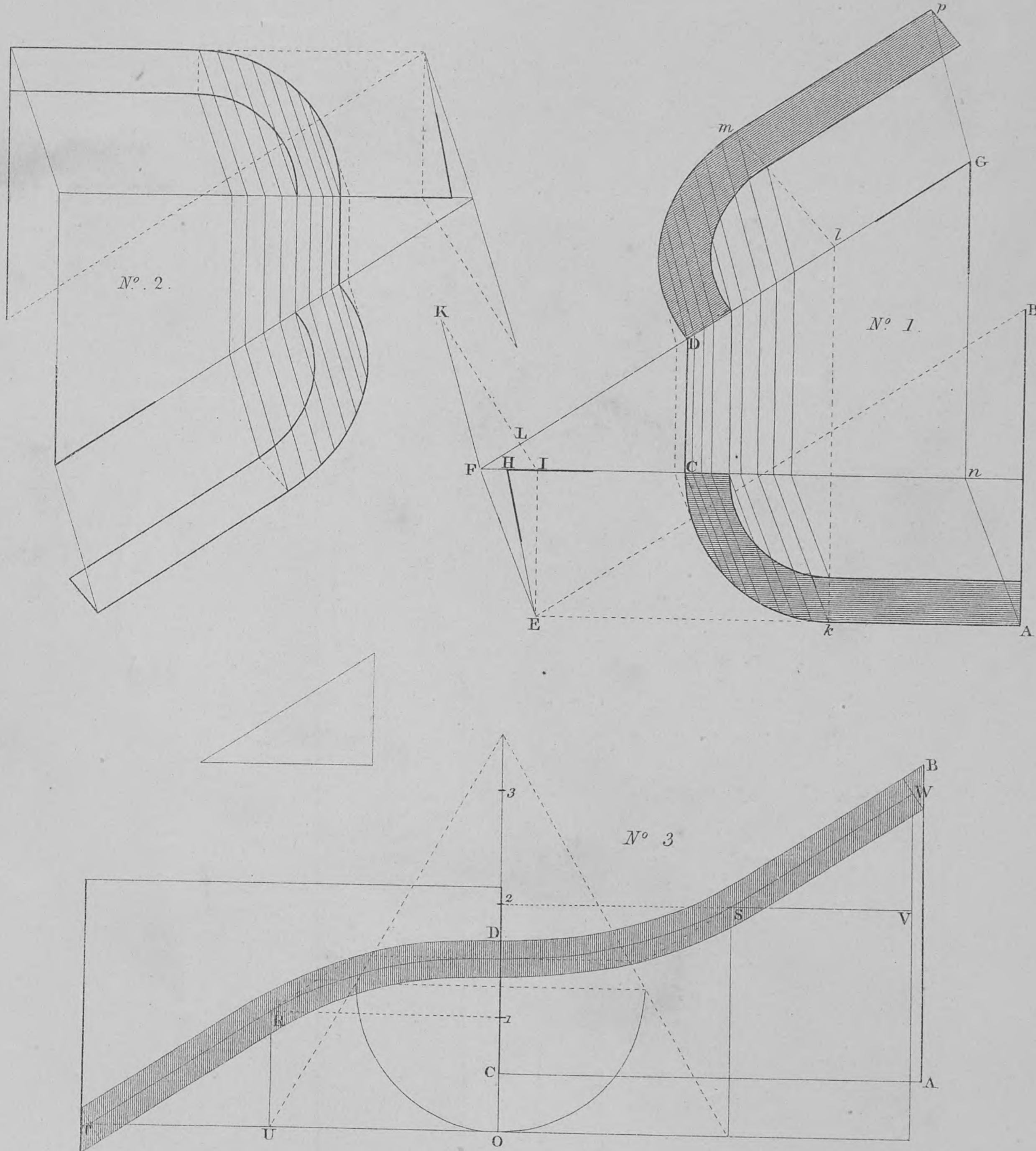


Drawn by P. Nicholson.

Engd by R. Thew

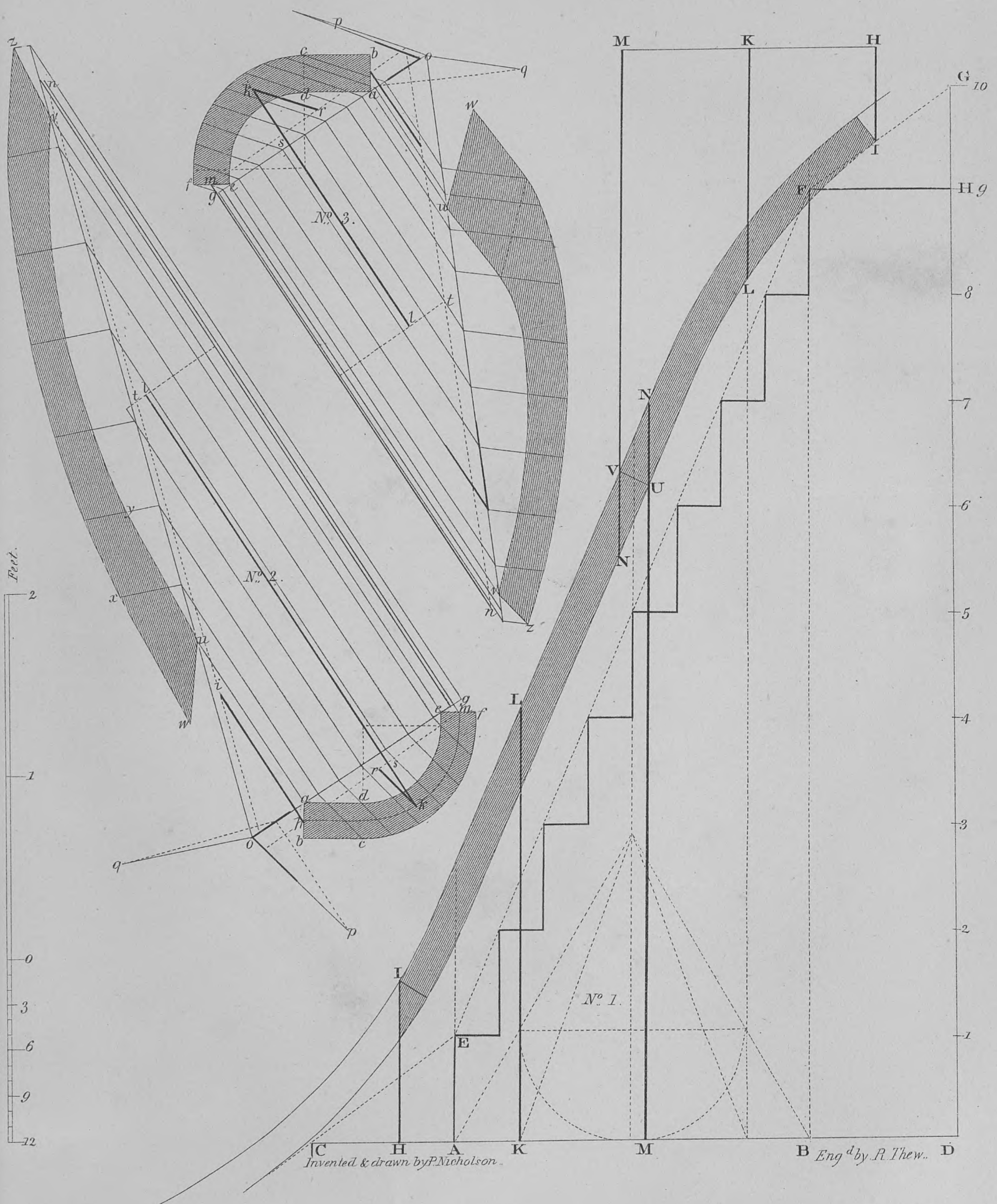
HAND RAILING.

PLATE III.



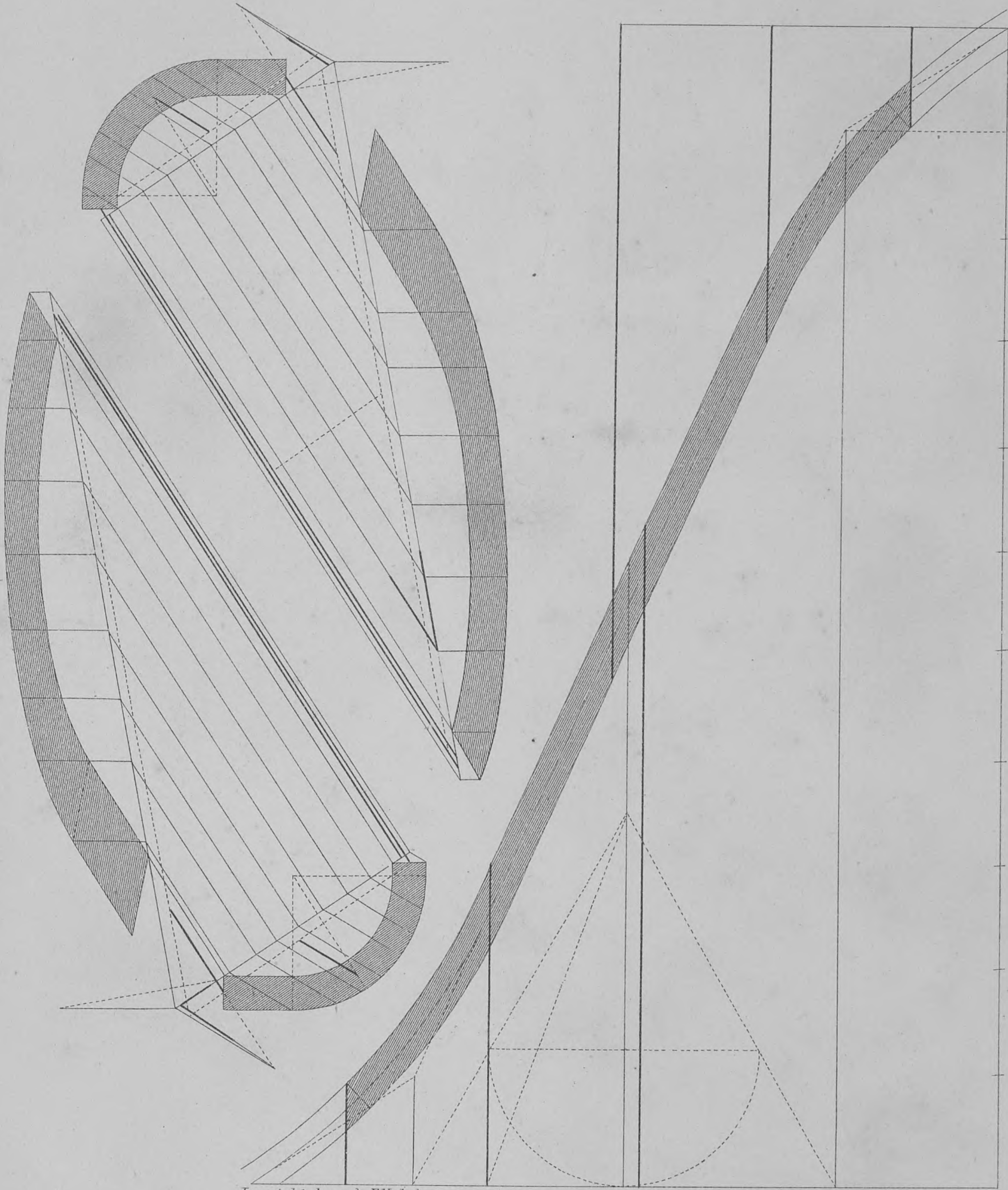
Invented & drawn by P. Nicholson.

Engd by R. Thew.



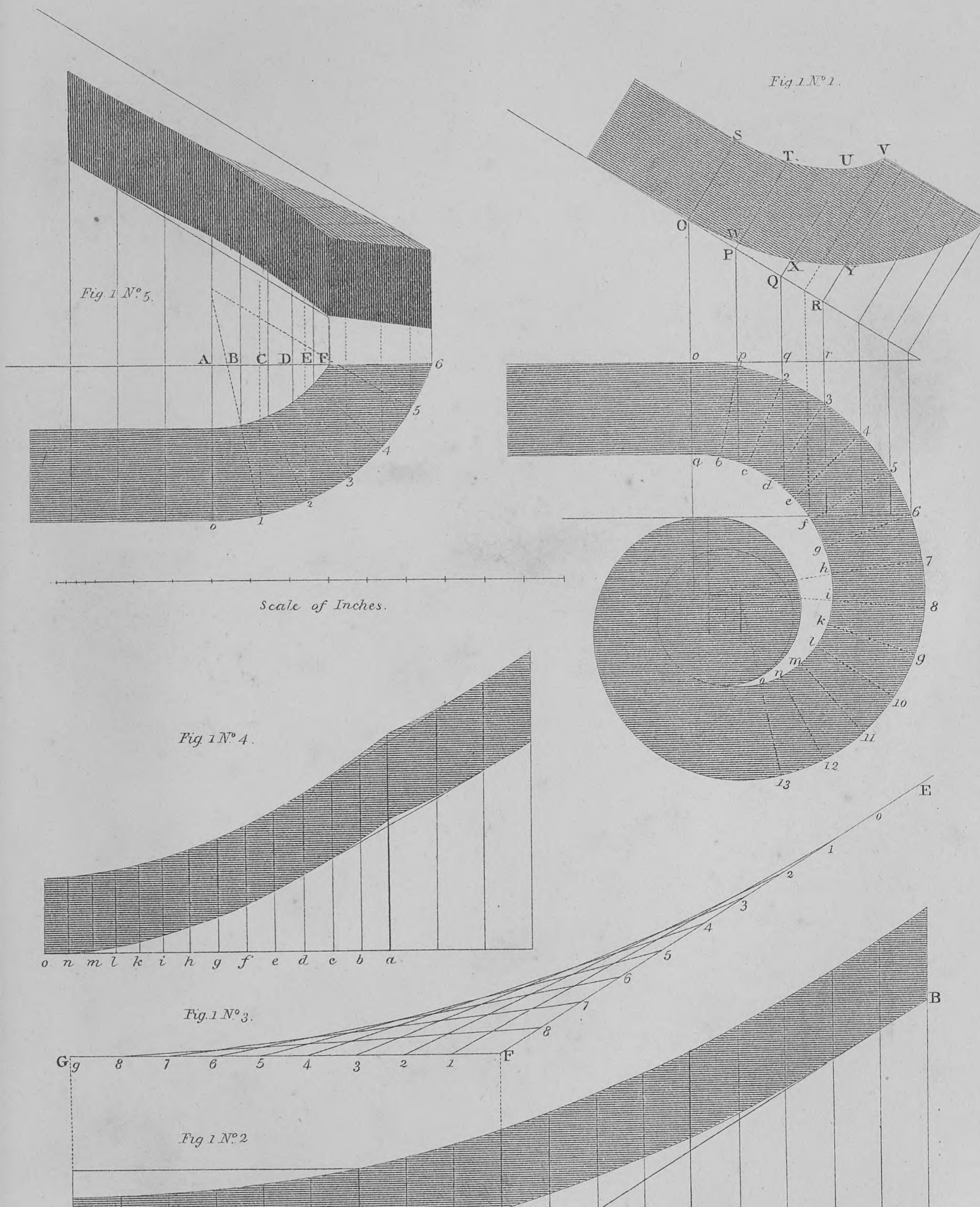
Invented & drawn by P. Nicholson.

Engd by R. Thew.



Invented & drawn by P. Nicholson.

Eng^d by R. Thew.



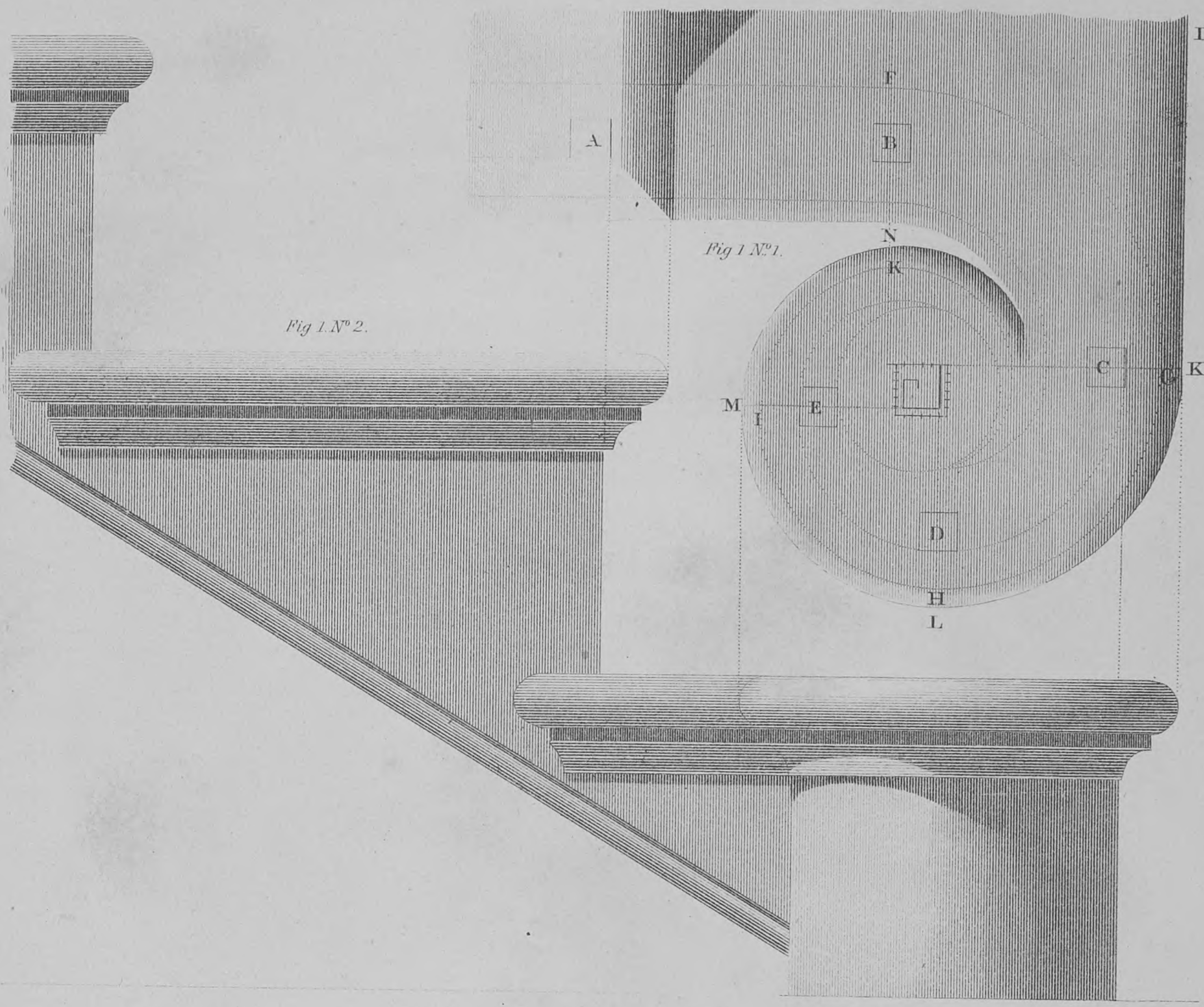
Invented by P. Nicholson.

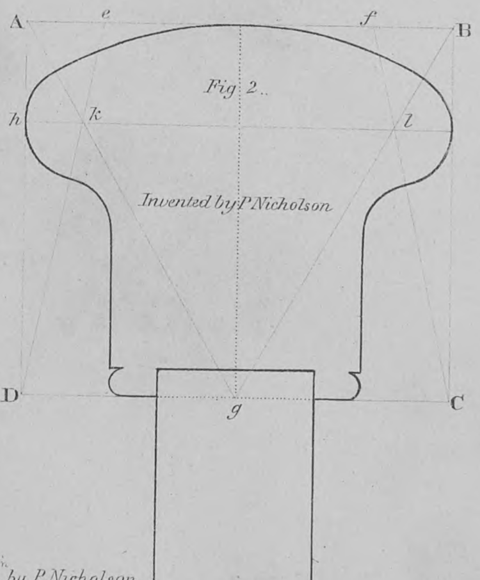
Engd by R. Thew.

HAND RAILING.

PLATE. VII.

Invented by P. Nicholson.





D. by P. Nicholson.

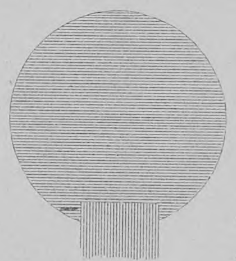
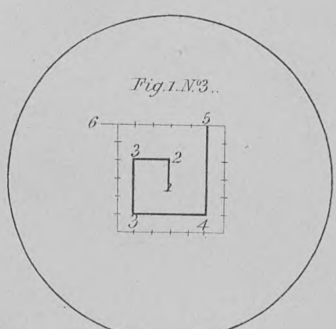
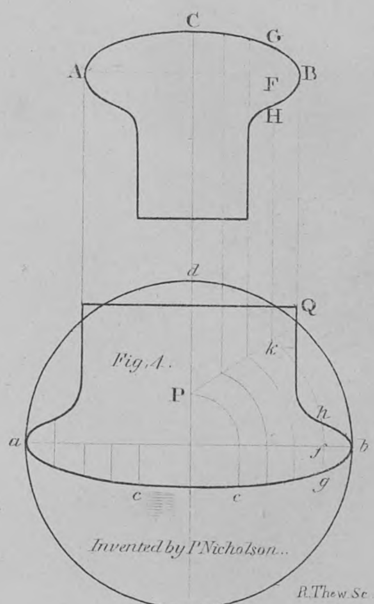


Fig. 3.

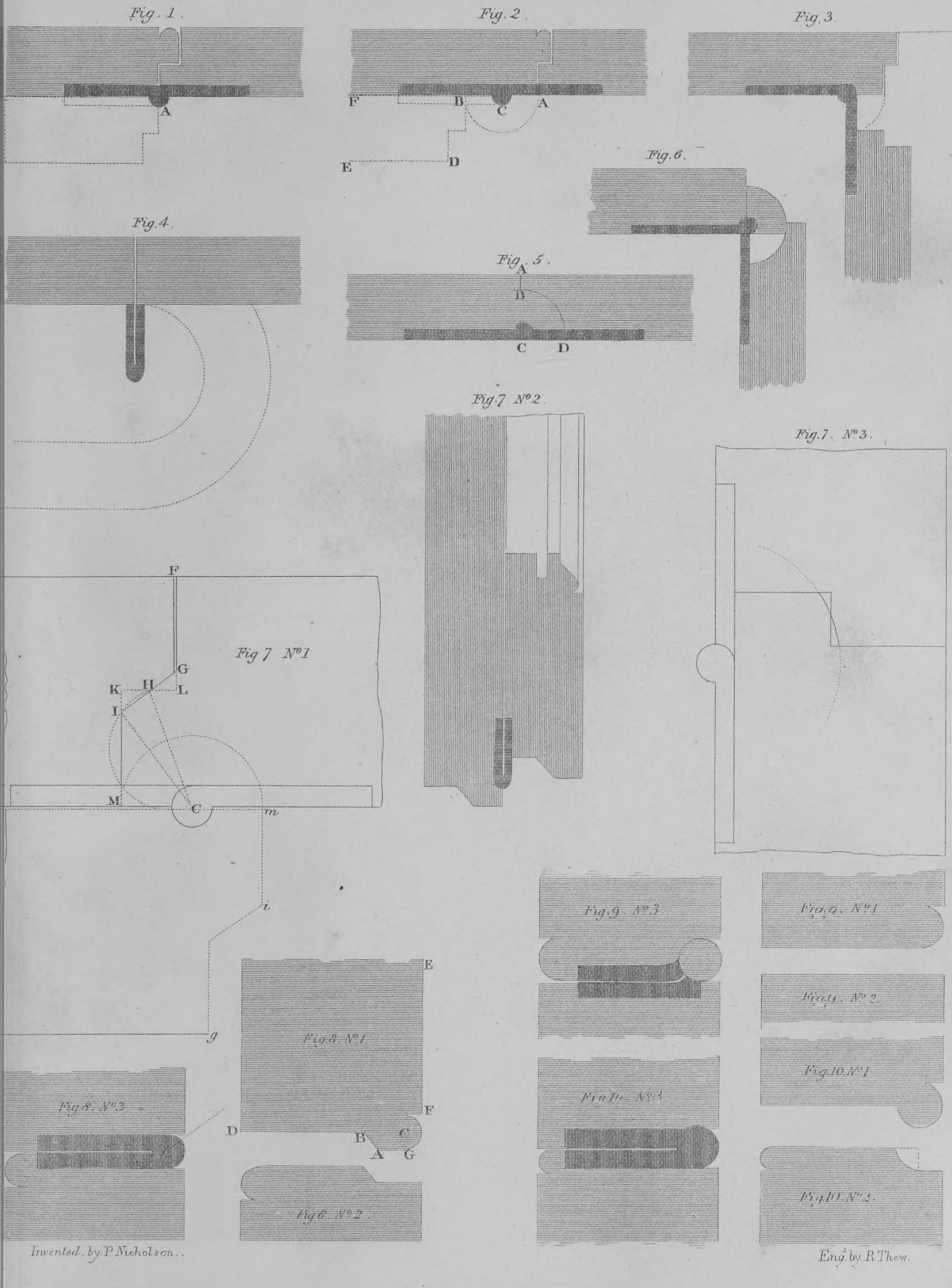




R. Thew Sc.

HINGING

PLATE. I.



Invented. by. P. Nicholson..

Engd. by. R. Thew.

Fig. 11. No. 3.

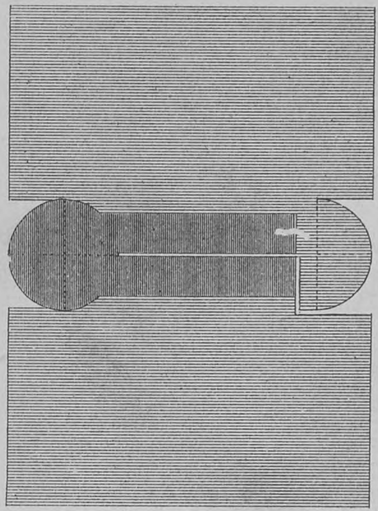


Fig. 11. No. 1.

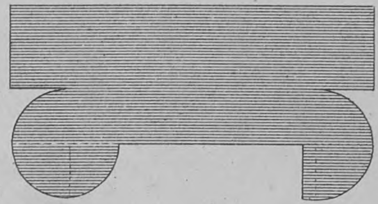


Fig. 12. No. 1.

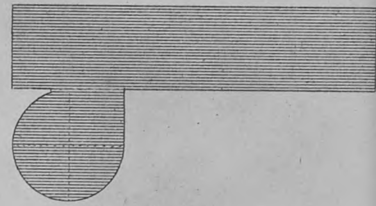


Fig. 11. No. 2.

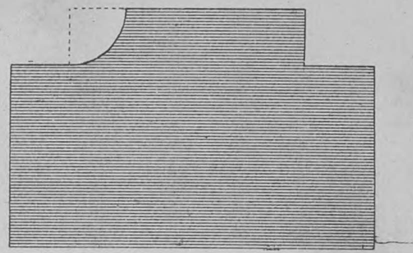


Fig. 12. No. 2.

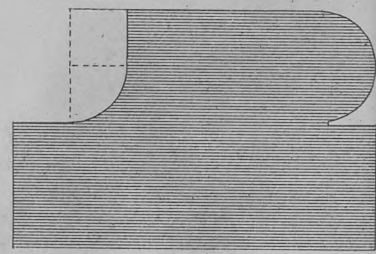


Fig. 12. No. 3.

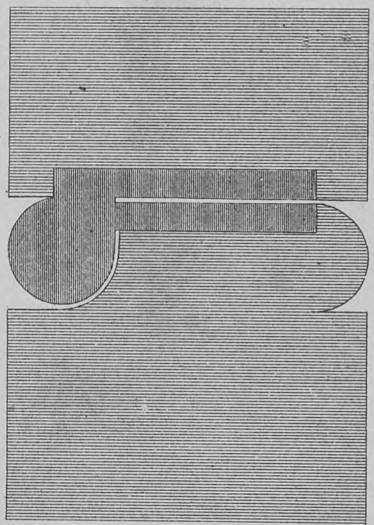
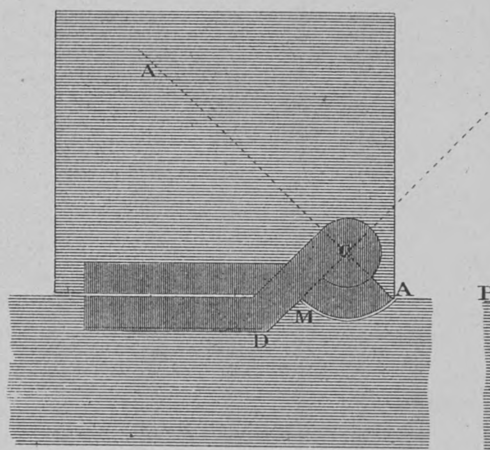


Fig. 14.



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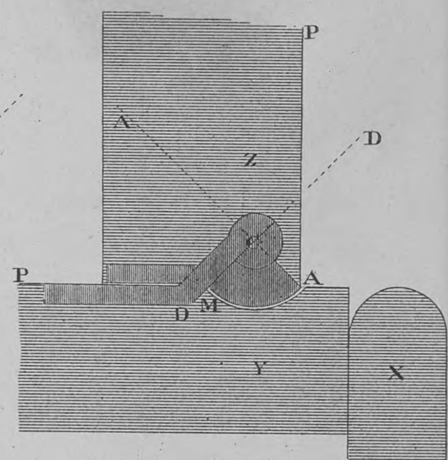

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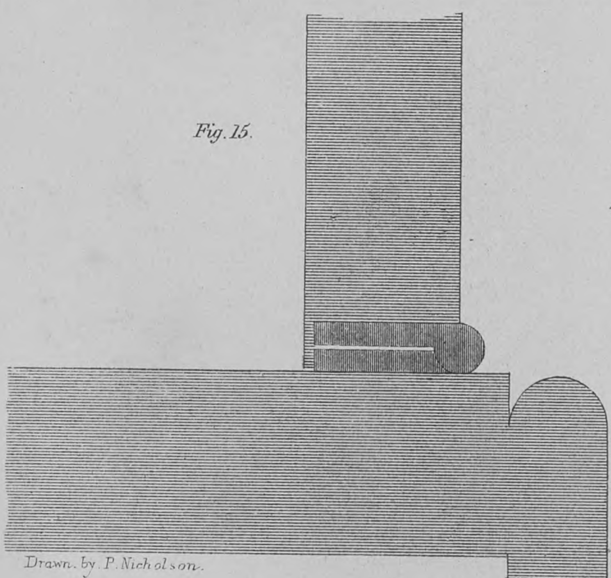
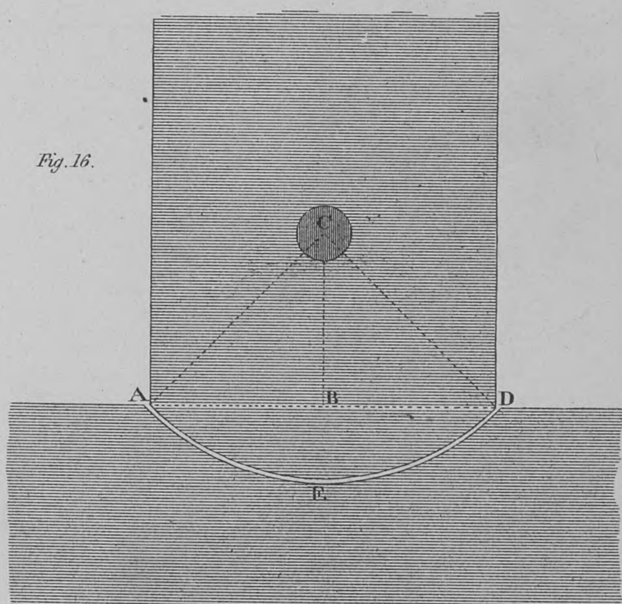


Fig. 16.



Drawn by P. Nicholson.

Engd by R. Thew.

HIP. ROOF.

PLATE. I.

Fig. 1.

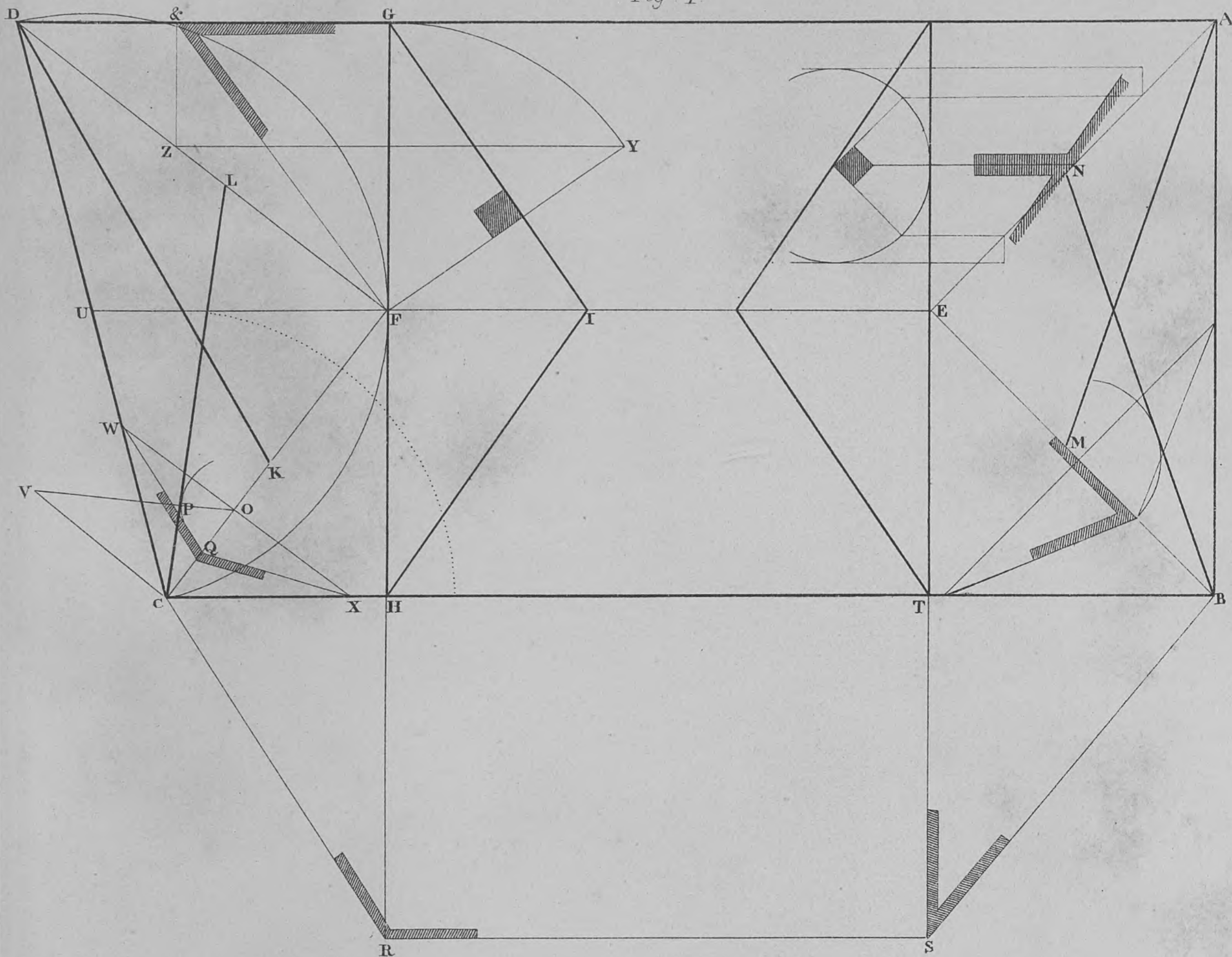
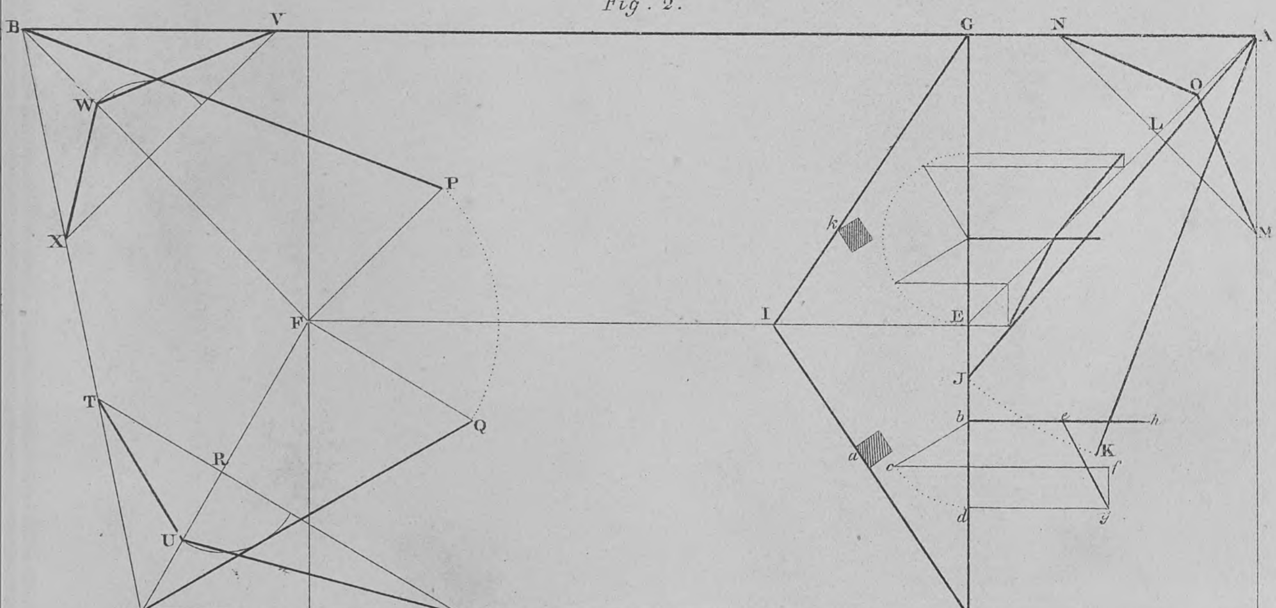


Fig. 2.



Drawn by P. Nicholson. *Eng.d by R. Thew.*

HIP ROOF.

PLATE II.

Fig. 5.

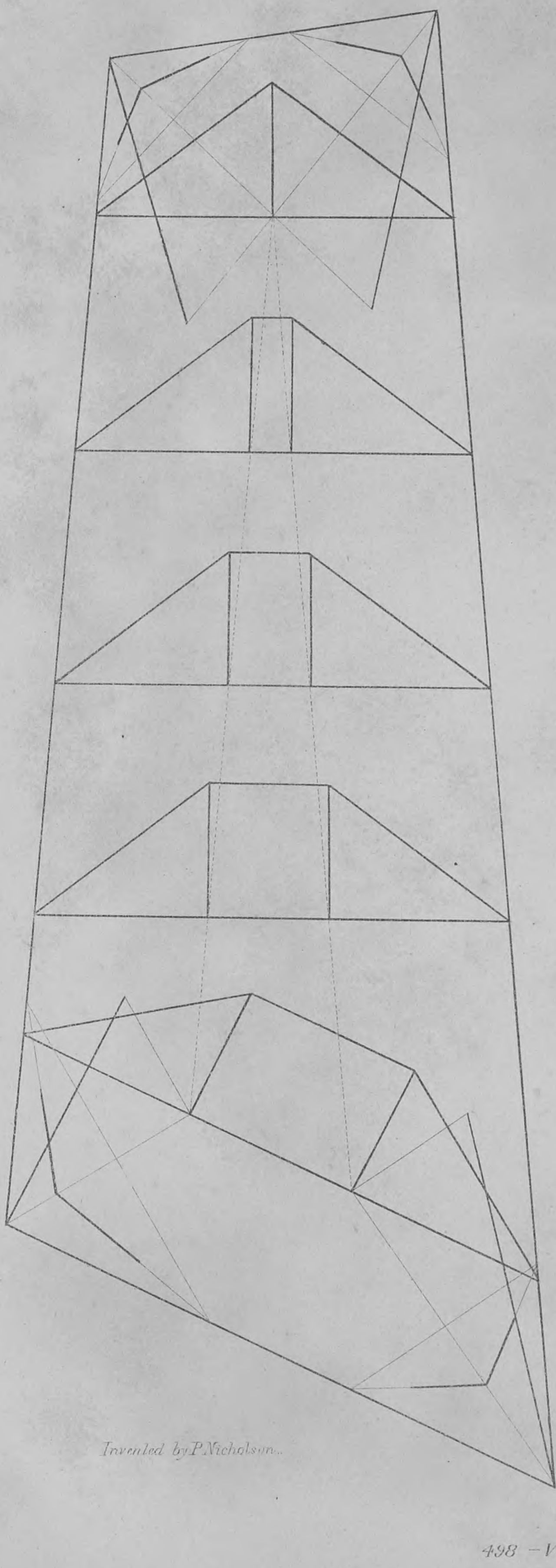
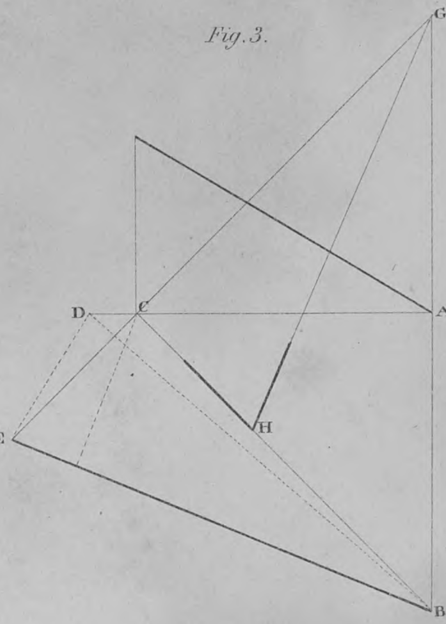


Fig. 3.



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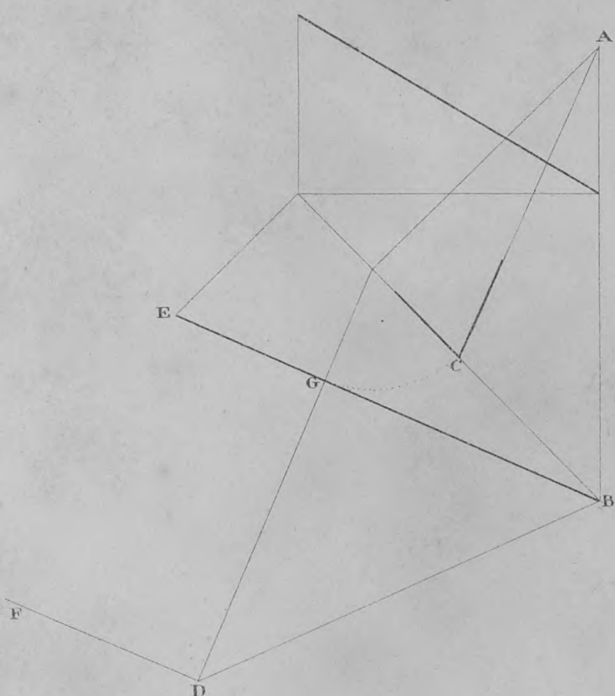

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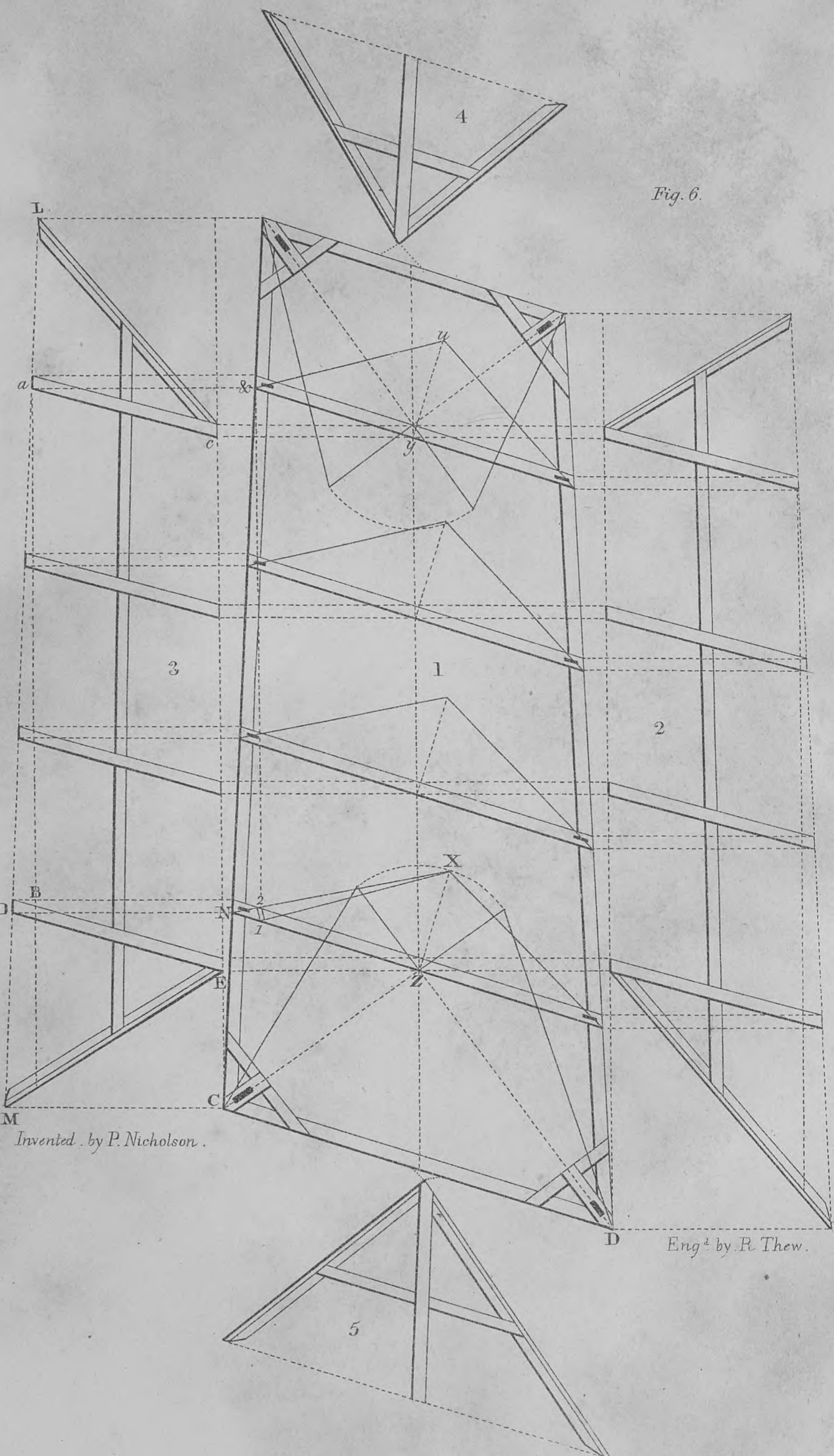


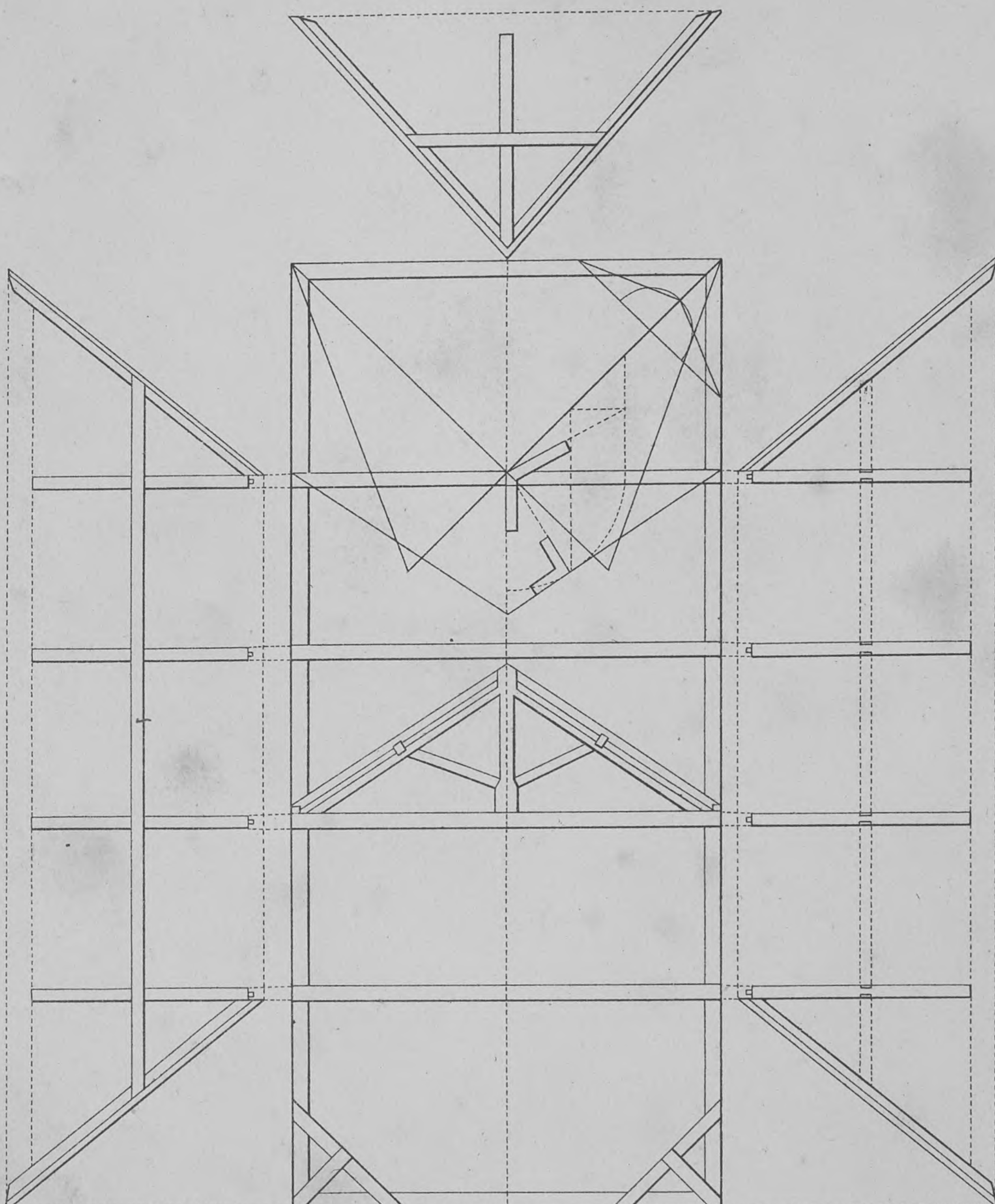
Invented. by P. Nicholson.

Engd by R. Thew.

HIP ROOF.

PLATE. IV.

Fig. 7.



Invented. by. P. Nicholson

Eng.d by. R. Thew.

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